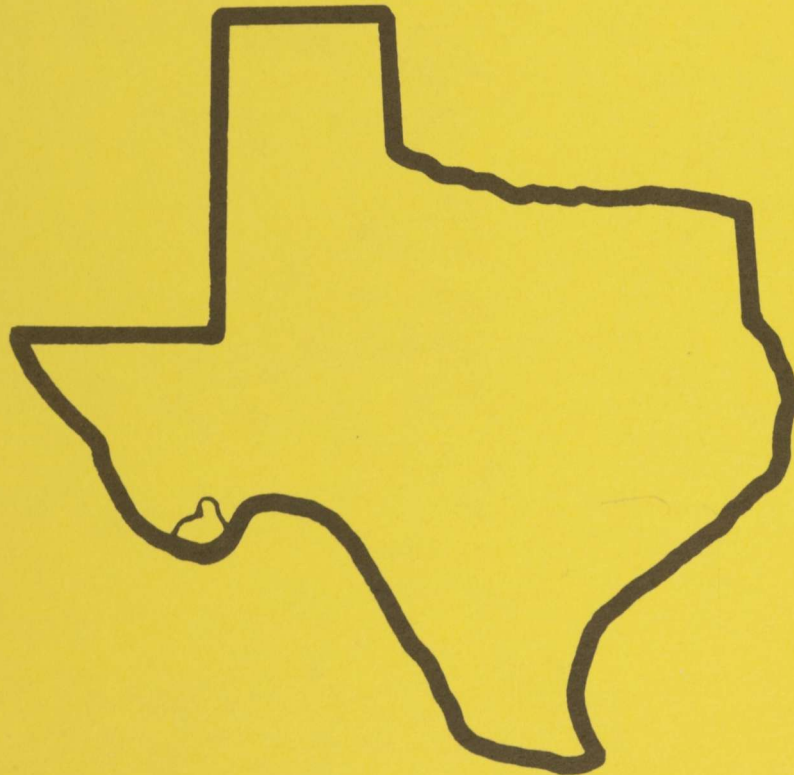# BULLETIN 24

TEXAS MEMORIAL MUSEUM

VERTEBRATE PALEONTOLOGY AND PALEOECOLOGY
OF PALEOCENE BLACK PEAKS FORMATION,
BIG BEND NATIONAL PARK, TEXAS

By Judith Ann Schiebout

THE UNIVERSITY OF TEXAS AT AUSTIN

BULLETIN

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VERTEBRATE PALEONTOLOGY AND PALEOECOLOGY OF
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ABSTRACT

The fauna of the Black Peaks Formation is the southernmost large Paleocene fauna of North America. It contains 29 species of mammals belonging to 28 genera and includes three new species, a barylambdid pantodont, a multituberculate, and an insectivore. The 170-meter (560-foot) thick formation has three principal faunal levels. The lowest level is latest Torrejonian or earliest Tiffanian in age, the second is early Tiffanian, and the third is Clarkforkian. The formation was deposited by meandering rivers; the climate in the region was semitropical to tropical with alternating wet and dry periods of greater than seasonal duration.

INTRODUCTION

Location

Three areas of exposure of the Black Peaks Formation are known. They lie within Brewster County, Texas (fig. 1; Maxwell *et al.,* 1967, pl. II). The largest area of exposure of the formation, the type section, the maximum thickness, and the most productive fossil localities are on western Tornillo Flat. Another area of exposure of the formation is on eastern Tornillo Flat, northwest of the McKinney Hills, and a third small exposure occurs about eight kilometers southwest of Tortuga Mountain on the southeast side of the Chisos Mountains in the upper drainage of Juniper Draw (Maxwell *et al.,* 1967, pl. II). Most of the exposure on western Tornillo Flat lies within Big Bend National Park, and the other two exposures are entirely within the park.

Regional Geologic Setting

The exposures of the Black Peaks Formation lie within the 65-kilometer-wide "sunken block," a Tertiary basin first described by Udden (1907, pp. 80-81). This sunken block is bounded by the Sierra del Carmen Mountains and the Santiago Mountains to the east and by the Mesa de Anguila and the Terlingua uplift to the west. These bounding structures expose Cretaceous marine rocks. The Sierra del Carmen range is a west-dipping monocline broken into northwest trending normal fault blocks, and the Santiago Mountains are formed by an asymmetrical anticline overturned to the southwest. Mesa de Anguila is a northwest trending tilted fault block bounded on the northeast by the Terlingua fault zone. North of Mesa de Anguila lies the broad arch of the Terlingua uplift (Maxwell *et al.,* 1967, p. 2, pl. I).

The exposures of the Black Peaks Formation on Tornillo Flat lie north of the Chisos Mountains and southeast of the Rosillos Mountains, and the exposure southeast of the Chisos Mountains lies north of Mariscal Mountain (fig. 1). The Chisos Mountains, which lie near the center of the sunken block, are composed of extrusive and intrusive igneous rocks. The Rosillos Mountains are formed by a laccolith, and Mariscal Mountain is an asymmetric, northwest trending anticline exposing lower Cretaceous limestone at its core (Maxwell *et al.,* 1967, pp. 186, 287).

Fossiliferous limestone pebbles in the Hannold Hill Formation indicate that relief was great enough in the early Eocene to expose some lower Cretaceous limestone. Volcanic activity which produced the lava flows and tuffs of the Chisos Formation and the younger South Rim Formation, which are exposed in the Chisos Mountains, began in late Eocene (Stevens, 1969); however, small igneous intrusions were emplaced earlier in the Boquillas, Pen, and Aguja Formations, probably in the Late Cretaceous (Maxwell *et al.,* 1967, p. 300). Uplift of the Chisos Mountains began in the Oligocene, and post-Oligocene emplacement of the Chisos Mountains pluton continued the uplift (Maxwell *et al.,* 1967, p. 302). Movements along the faults that define the sunken block were probably continuous through the Miocene (Stevens, 1969). Deposition of the "Fingers Formation" [an in-

formal term used by Stevens (1969, p. 43)], the age of which has not been determined, accompanied the last main episode of faulting.

The nearest continental Paleocene rocks to the Big Bend area are in the San Juan Basin of northwestern New Mexico and southwestern Colorado, approximately 820 kilometers away. Matthew (1937) described the Paleocene faunas and discussed the stratigraphy of that area. Paleocene marine deposits, mainly shale, of the Midway Formation are exposed in southern and eastern Maverick County, Texas, approximately 340 kilometers from western Tornillo Flat. These deposits were described by Trowbridge (1931, pp. 28-37, pl. 3). Rainwater (1960) gives a general discussion of the Paleocene deposits of the Gulf Coastal Plain. Murray et al. (1959) reported the occurrence of Paleocene (Danian) nautiloids in rocks in southern Coahuila, 485 kilometers from western Tornillo Flat, which were later assigned to the Rancho Nuevo Formation (Murray et al., 1962). Hasseltine (1968) described upper Cretaceous and lower Tertiary rocks of the Los Encinas and Rancho Nuevo Formations in southern Coahuila, Mexico. He believed that some beds might be continental rocks of Paleocene age.

A small collection of fossil mammals has been recovered from the Punta Prieta-Rancho Rosarito locality 515 kilometers south of Ensenada in Baha California, Mexico (Morris, 1968) approximately 1,000 kilometers west of Big Bend (fig. 32). Morris (1968, p. 2) tentatively favored a late Paleocene age for the collection, but stated that it could be Tiffanian or Wasatchian. In an earlier paper Morris (1966) used the term "Clarkforkian" (pp. 3, 43-44) for the age of this Baja fauna. If the Baja California locality is considered to be Paleocene, it is the southernmost Paleocene mammal locality in North America. As yet, the Baja locality has yielded only four genera of mammals. The Black Peaks Formation has yielded the southernmost large Paleocene fossil mammal fauna yet discovered in North America.

Previous Work

Hill and Udden (1904) published a geologic map, unaccompanied by text, that included the areas of exposure of the Black Peaks Formation. A note on the map states that W. B. Phillips, B. F. Hill, and J. A. Udden did the field work. They considered deposits in the areas of exposure of the Black Peaks Formation to be "Late Upper Cretaceous (sic)" and stated that "Late Upper Cretaceous beds" were those younger than the Taylor marls. Results of Udden's work for The University of Texas Mineral Survey (Udden, 1907) include the naming and description of the Tornillo clays. The Tornillo clays included the rocks now assigned to the Black Peaks Formation. Udden believed that the Tornillo clays were marine deposits of Cretaceous age (Udden, 1907, pp. 17, 60).

Maxwell, who began work in the Big Bend area in 1936 and became first superintendent of Big Bend National Park in 1944, authored or co-authored several geological guidebooks on the area: Maxwell (1941), Maxwell et al. (1949), Lonsdale et al. (1955), and Maxwell and Dietrich (1965). In Maxwell et al. (1967), work by Lonsdale on igneous intrusives, by Hazzard on stratigraphy, and by Wilson on fossil mammals was combined with Maxwell's extensive description of the region's stratigraphy and structure. The Javelina Formation, the Black Peaks Formation, the Hannold Hill Formation, and the Canoe Formation were formed from Udden's Tornillo clays and were named in Maxwell et al. (1967).

Previous sedimentological studies in Big Bend National Park include those of Hopkins (1965) on the upper Cretaceous Aguja Formation, Lawson (1972) on the upper Cretaceous Javelina Formation, and J. B. Stevens (1969) on the Miocene and later deposits of the Castolon area in the southwestern part of Big Bend National Park. A detailed sedimentological study (Schiebout, 1970) of the Black Peaks Formation was made on western Tornillo Flat where the type section of the formation and the most productive fossil localities are found. This study was an attempt to determine the sources of the sediments in which the fossils were entombed and the environment of deposition. Samples of mudstone from the Black Peaks Formation were treated to extract pollen for a study of the flora, but no pollen was recovered (Schiebout, 1970, p. 61).

Acknowledgments

This study was suggested and supervised

Stratigraphy

The Black Peaks Formation was named after three small basaltic peaks found in the area of exposure of the formation northwest of the McKinney Hills on eastern Tornillo Flat (fig. 1; Maxwell *et al.,* 1967, p. 98, pl. II). The underlying Javelina, the Black Peaks, and the overlying Hannold Hill Formations were named in Maxwell *et al.* (1967, pp. 88-107) as units of their new Tornillo Group, which overlies the Aguja Formation. Maxwell *et al.* (1967, p. 88) described the Javelina Formation as being Late Cretaceous, the Black Peaks Formation as Paleocene, and the Hannold Hill Formation as early Eocene. The fauna of the Aguja Formation is of late Campanian age according to Maxwell *et al.* (1967, p. 87). The Javelina Formation contains dinosaur remains that indicate a Maestrichtian age according to Lawson (1972, p. 112). Wilson *et al.* (1952) and Wilson (1967) concluded that animals of both Torrejonian and Tiffanian age were present in the Black Peaks Formation. New collections of mammals from western Tornillo Flat have made possible both more precise correlation with other faunas and an attempt at detection of stratigraphic changes in fauna within the formation (fig. 34). These new collections include fossils found both stratigraphically lower and higher than those previously described from the area. No fossils indicating an age older than Paleocene have been recovered; however, the possibility that some of the formation is Eocene has considerably increased. The stratigraphically highest fossiliferous level may be assigned to the Clarkforkian age. The remaining 45 meters of the formation above this level has not yielded identifiable fossils. The overlying Hannold Hill Formation contains early Eocene (Wasatchian) mammals (Wilson, 1967, pp. 165-166).

Throughout this paper I have used the North American Mammal Age *Clarkforkian* (Wood *et al.,* 1941). I am aware that there is controversy over the validity of the Clarkforkian (Wood, 1967; Russell, 1967; Sloan, 1969; D. Parris, 1971, pers. comm.). At the present time no revised limits for the Tiffanian, Wasatchian, or Clarkforkian have been proposed, and until such time, I propose to follow Wood

et al. (1941). It is beyond the scope of this paper to re-define these ages.

The type section, where the Black Peaks Formation has its maximum thickness, is 264 meters (866 feet) thick according to plane table measurements by Maxwell et al. (1967, pl. II; pl. IX, sec. 33). I measured 170 meters (560 feet) to the top of the uppermost sandstone in this section with a Jacob's staff and Brunton compass, compared with their measurement of 236 meters (775 feet) to the same level. The 4.6 meters (15 feet) of mudstone overlying the covered interval above this sandstone in the type section (Maxwell et al., 1967, pl. IX, sec. 33) has been covered by alluvium, so that this sandstone is the uppermost exposed rock of the formation. A four-degree difference in dip would account for the difference in measured thickness.

I was not able to use the type section (Maxwell et al., 1967, pl. IX, sec. 33; p. 101) to determine the level in the formation of my sedimentological samples and fossil localities, although the beginning point of their section and the outcrop of the uppermost sandstone are easily located from aerial photos. The sandstone bodies are variable in thickness and in sequence of sedimentary structures, so, despite their detailed descriptions (Maxwell et al., 1967, p. 101), I was never able to determine which particular unit was being described. The distinctive and laterally extensive mudstone layers, which I used as stratigraphic markers (fig. 6), were lumped together in the description by Maxwell et al. (1967, p. 101). The height of 229 meters (750 feet) for locality T1 given in Maxwell et al. (1967, p. 101) is an error. T1 is a general locality number for the exposures of the Black Peaks Formation on western Tornillo Flat. Before 1968 no fossil mammals had been recovered from the upper one-fifth of the Black Peaks Formation in this area, and few had been recovered from the upper half of the formation. All information on levels in formation in this paper are from my own measurements (figs. 3, 34).

Level above the base of the formation is given in descriptions of localities without any implication that similar levels at the other areas of exposure (fig. 1) are synchronous. The levels of localities (tables 1, 2, fig. 34) on western Tornillo Flat indicate the stratigraphic relationship of those localities to one another, but are not meaningful stratigraphically in comparison to levels above the base of the formation at the other two exposures.

The base of the Black Peaks Formation in its type section was placed at the base of a platy white sandstone (Maxwell et al., 1967, pl. IX, sec. 33). An unconformity was shown at the base. No unconformities were shown within the type section. The amount of erosion observed at the base of the lowest sandstone of the Black Peaks Formation is no greater, however, than the amount of erosion seen at the bases of other thick sandstones within the formation. The top of the Black Peaks Formation on western Tornillo Flat was placed at the base of a massive gray sandstone with an irregular base which was considered to be the base of the overlying Hannold Hill Formation (Maxwell et al., 1967, pp. 102-103). The Hannold Hill Formation is composed mainly of gray and maroon clay and contains less sandstone than the Black Peaks Formation.

Hopkins (1965) stated that the Aguja Formation records a regression of the sea. According to Hopkins (1965) interbedded sandstone and claystone of the lower part of the Aguja Formation was deposited in a tidal flat environment, lignitic shale with thin coal seams in the middle of the formation was deposited in a marsh environment, and claystone accumulated in lagoons. Maroon and gray claystone with interbedded sandstone lenses of the upper Aguja were deposited on coastal river floodplains. The Javelina Formation, predominantly multicolored claystone containing some lenses of sandstone, was deposited on a floodplain according to Maxwell et al. (1967, p. 92) and on an alluvial fan according to Lawson (1972). I consider the depositional environments discussed by Lawson (1972) to be more characteristic of floodplain than alluvial fan deposition. "The Black Peaks Formation is an alternation of sandstone and clay, much like the upper part of the Aguja Formation. . . ." (Maxwell et al., 1967, p. 98). Like the upper Aguja, it is a floodplain deposit.

Topography and Climate

The best exposures of the Black Peaks Formation occur in badlands (fig. 6). Sandstone bodies form low ridges or cap mesas. Sides of weathered mudstone hills slope up to 65 degrees.

Features similar to those found in a karst-land have developed in parts of the badlands. In a true karstland, solution is the dominant erosional process (Sweeting, 1968, p. 582). In the Black Peaks Formation, slip planes in mudstone allow penetration of water to begin conduit formation through disaggregation, and sinkhole-like structures result. Similar karst-like terrain has developed on claystones of the Chinle Formation in badlands of the Petrified Forest in Arizona (Mears, 1963).

Rillensteine, weathered grooved or chan-neled rocks with the rills less than a millimeter wide, are common in float. Rills occur on mi-crocrystalline calcite nodules weathered from the Black Peaks Formation. Rilling is produced through solution by carbonic-acid-bearing rain-water in arid regions (Laudermilk and Wood-ford, 1932).

Vegetation is sparse on exposures of the Black Peaks Formation. A few yuccas *(Yucca* sp.) and the screwbean or Tornillo mesquite *(Strombocarpa odorata)* occur in dry creek beds. Lechuguilla *(Agave lechuguilla),* prickly pear cactus *(Opuntia* sp.),pitaya cactus *(Echinoceras* sp.), and greasewood *(Larrea di-varicata)* occur on areas capped with younger gravel (Ammon, 1965), and greasewood is locally common on the alluviated flats.

Infrequent, primarily summer, thunder-storms provide most of the rain in the Big Bend. A rainstorm over the Rosillos Mountains can transform bone-dry Tornillo Creek into a half-kilometer-wide river in a few hours. Away from the creeks, tire tracks may remain clearly visible for as much as a year. Summer tem-peratures exceed 100 degrees F.

Definitions

Eutherian Tooth Nomenclature

The tooth nomenclature (fig. 4) is that of Szalay (1969). Except for minor modifications it is the Osbornian nomenclature used in the vertebrate paleontological literature during this century. Vandebroek (1961) and Hershkovitz (1971) have recently proposed a new and con-troversial nomenclature based on their con-cepts of dental homologies and evolution. It is subject to modification whereas the Osborn-ian nomenclature is stable. The Osbornian nomenclature reflects some ideas of dental evolution that are no longer accepted, but it

is useful in a descriptive (i.e., geographic) sense and is thus employed here.

Length measurements on teeth were taken as the maximum tooth diameter parallel to the tooth row in the immediate region of the jaw. Width measurements are maximum diameters perpendicular to the length. Orientation in the tooth row was estimated for loose teeth (fig. 5).

Symbols and Abbreviations

Definitions for statistical symbols listed be-low are derived from those of Simpson *et al.* (1960). All measurements are in millimeters unless otherwise indicated. A probability of 95 percent was used as the significance level for t-tests.

AMNH:	American Museum of Natural History
CNHM:	Chicago Natural History Museum
est.:	estimated measurement
min.:	minimum measurement. Used when specimen is broken or crushed so that the actual measurement is slightly less than the original.
N:	total number in sample
P:	tabulated probability from a stan-dard probability distribution
TMM*:	Texas Memorial Museum, Austin
trans:	transverse
PU:	Princeton University
USNM:	United States National Museum
V:	coefficient of variation
$\bar{X}$:	mean
?	before a name, indicates uncertainty of application of that name; before a specimen number, specimen is re-ferred with hesitancy to that taxo-nomic group; before a tooth name, indicates uncertainty that the speci-men is that tooth.
[]	Preceded by a name in quotation marks, brackets indicate that the preceding name is a synonym, at least in part, of the contained name.

*Specimens at The University of Texas at Austin formerly under care of the Bureau of Economic Geology bore the pre-fix BEG. All fossil vertebrates at The University of Texas at Austin now are in the TMM collection. Specimen numbers without prefixes belong to the TMM; such numbers preceded by a hyphen are abbreviated and include the five-digit locality number preceding. Description of numbered localities is given in table 1.

SEDIMENTOLOGY

The following information on the sedimentology of the Black Peaks Formation, studied on western Tornillo Flat, has been condensed from Schiebout (1970). I have used terminology from Folk's (1968) classification for sedimentary rocks throughout.

Lithology

Extrapolating from conditions seen at the outcrops, approximately 60 percent by volume of the formation is mudstone; the rest is sandstone, except for small conglomerate scour fills that comprise less than two percent. Mudstone includes silt-size and clay-size material and mixtures of all proportions (Folk, 1968, p. 30). Most sandstone is fine grained; however, some very fine-grained and medium-grained sandstone is present.

Most of the sandstone occurs in thick bodies (3-12 meters) which show a characteristic sequence of bedding and grain size changes (fig. 7). They vary greatly in thickness. The bases of the sandstone bodies roughly parallel the color banding in the mudstone, but 0.3 to 1 meter of irregular scour is common. Most of the thick bodies are continuous as far as they are exposed on western Tornillo Flat. Where they can be observed to terminate laterally, they grade into thin sandstone and siltstone layers interbedded with mudstone. Cross bed sets are thicker in the lower part of thick sandstone bodies than in the upper part; grain size commonly becomes finer upwards. Trough cross beds predominate in the lower parts. Shallow trough cross beds, ripple cross beds, and cross bed sets having planar or near-planar beds predominate in the upper parts of the thick sandstone bodies. Conglomerate lenses are more common in the trough cross bed scours of the lower parts of the sandstone bodies than they are in scours in the finer grained sandstone of the upper portions. Thin discontinuous sandstone layers, usually from 15 centimeters to one meter in thickness, are a minor part of the formation. They either lack bedding or contain ripple cross beds or horizontal laminations.

Small conglomerate lenses occur in both the sandstone and the mudstone. Fragments of microcrystalline calcite nodules are the main gravel-sized (> 2 mm diam.) conglomerate component. Similar whole nodules are common in the Black Peaks Formation and in the underlying Javelina Formation and Aguja Formation (Hopkins, 1965, p. 19).

Mudstone layers of one color, usually 0.3 to 1.5 meter thick, appear from a distance to be continuous and to have sharp boundaries (fig. 6). The mudstones are shades of red, black, gray, yellow, and gray-green. Most of the mudstone shows no primary sedimentary structures, such as laminations, and no orientation of detrital inclusions. The color layers visible at a distance are not bounded by bedding planes, but by gradual shifts in the predominant color of the mottled rocks. Rarely, laminations less than 1 mm thick can be seen in the mudstones. Black mudstone contains little or no calcite cement and no calcite nodules, but mudstone of other colors is usually firmly calcite cemented and contains calcite nodules (p. 7). These nodules are especially abundant in some red mudstones.

Structures

The most common sedimentary structures are cross beds, laminations, and current lineations. Trough cross beds in the sandstone formed when scours were filled by advancing sand waves. Ripple cross beds differ from the trough cross beds only in scale. They were formed by sand ripples migrating into small trough-shaped scours. The concavity of trough cross bed sets commonly decreases upwards within sandstone bodies. Cross bed sets in the sandstone having planar or near-planar beds sometimes show primary current lineation, shallow parallel hollows and ridges on the bedding planes, which indicate that the beds formed under high flow-regime conditions (Allen, 1964). Sets of thin planar laminae, which truncate one another in places, and ripple cross bedding are the primary sedimentary structures in the mudstone. Some bedding, especially in mudstone, has been destroyed by the activities of animals, by roots, and by post-depositional movement.

Chemical structures such as concretions and nodules are common. Concretions differ from nodules in that they are formed by orderly precipitation around a nucleus; nodules lack internal structure (Pettijohn, 1957, p. 197). Round concretions in sandstone, called can-

nonball concretions, are similar in composition to the surrounding sandstone except that they are firmly cemented by calcite precipitated in sediment pores around a nucleus. Some lack a conspicuous center of growth; others contain a small calcite nodule. Small iron-oxide-cemented concretions, called shot concretions, are locally common on bedding planes. They formed around small concentrations of iron-bearing heavy minerals or rock fragments. In calcareous mudstone, microcrystalline calcite nodules are common, and botryoidal calcite spherulite aggregates are locally common. Spherulites may have formed around bits of decaying organic matter which released ammonia causing the precipitation of calcite (Degens *et al.,* 1964). Most nodules are of irregular shape and show no regular structure in thin section. Scattered veins of coarser calcite in them narrow toward the concretion surface like the veins in septarian nodules (Pettijohn, 1957, p. 209). The nodules were once masses of calcareous matter formed in soils or in burrows or in holes left by the decay of roots (fig. 10). As they dried, the cracks formed. Calcite was deposited in these cracks to form the veins.

Petrography

Thin sections of 13 sandstones and one siltstone were point counted to determine their mineralogical composition. Most of the sandstone is feldspathic litharenite or lithic arkose according to the sandstone mineralogical classification of Folk (1968). Because the fragments of older rocks in them are mostly volcanic rock fragments, the feldspathic litharenites are more accurately called feldspathic volcanic-arenites. A grain size analysis of 13 sandstone samples, including the 11 which had been point counted and could be disaggregated, showed most of them to be fine sandstone, very fine sandstone, or very fine muddy sandstone. Average quartz roundness is subangular or angular.

The only clay in the three mudstone samples which were X-rayed is montmorillonite. Clay in the matrixes of sandstone is montmorillonite or high iron chlorite or a mixture of both.

Among the heavy mineral varieties recovered from the sandstones were magnetite, ilmenite, tourmaline, and zircon. Idiomorphic, hypidio-

morphic, and well-rounded zircon grains occur in the heavy mineral separates, and all three varieties occur together in one slide. Many of the zircon grains contain tubular fluid inclusions. Most are colorless. Rounded and angular tourmaline also occur together.

Direction of Transport

The direction of dip of sandstone beds and the orientation of fossil logs were used to obtain an estimate of the direction of sediment transport. The average direction of transport for western Tornillo Flat was to the south or southeast. The rivers which deposited the Black Peaks Formation probably drained into the Gulf of Mexico (fig. 32).

Provenance

At least two different types of source rock, if not two different source areas, contributed detritus. Variation in roundness within heavy mineral varieties indicates that the heavy mineral grains underwent different amounts of abrasion. Some grains may have passed through several sedimentary cycles, while others, such as idiomorphic zircons with fresh, unscarred crystal faces, passed through only one cycle.

Older sedimentary rocks, both clastic and carbonate, contributed material. A few well-rounded quartz grains with reworked quartz overgrowths seen in thin section were inherited from an older formation. Some chert fragments in the sandstone showed iron-stained dolomite rhomb-shaped ghosts. This chert probably formed by replacement of carbonate rock which contained dolomite crystals. No fragments of older limestones have been identified from the formation; however, solution of Cretaceous limestone could have provided calcium carbonate for the formation of cement and nodules in the Black Peaks rocks. The underlying Cretaceous formations exposed by uplifts to the west may have been a sedimentary rock source. For example, the Aguja Formation as described by Hopkins (1965, p. 62) and the Javelina Formation (Lawson, 1972, p. 46) contain volcanic rock fragments similar to those in the Black Peaks Formation. Both the Aguja and Javelina Formations contain much bentonitic clay. The Black Peaks Formation and these underlying formations may

have been derived from the same or similar source areas, or much material in the Black Peaks Formation may have been derived from the older formations by reworking. The alluvial plain conditions (pp. 38-39) and the lack of coarse material preclude the presence of local high relief during deposition of the Black Peaks Formation. Both the underlying Javelina Formation (Lawson, 1972, pers. comm.) and the overlying Hannold Hill Formation, however, contain reworked Cretaceous limestone pebbles, which indicates some local tectonic activity.

Although some volcanic material, such as the volcanic rock fragments and the montmorillonitic mud, could have been reworked, some, such as the fresh, idiomorphic and hypidiomorphic zoned feldspars present throughout the section, were probably derived in one cycle from a volcanic rock source. Callender and Folk (1958) have found an almost perfect correlation between occurrence of idiomorphic zircon grains such as those found in the Black Peaks Formation and evidence for large contributions of volcanic detritus in the lower Tertiary sands of central Texas. Weathering of ash falls produces montmorillonite (Folk, 1968, p. 93). No ash falls have been identified in the Black Peaks Formation; no glass shards have been seen in the mudstones. Cenozoic volcanic activity in the Big Bend region began in late Eocene (Stevens, 1969); therefore, fresh volcanic detritus must have come from farther west.

OCCURRENCE OF FOSSILS

Preservation

Mammal teeth and bones are not abundant except where they have been concentrated, either during the Paleocene in conglomerate lenses, or by recent weathering in float. The name "bonebed," which is applied to several localities (table 2), is euphemistic. Bonebeds are areas which yield isolated bones and jaw fragments fairly steadily when visited year after year. For example, Joe's Bonebed is a mudstone ridge covered with nodule float, with a few small conglomerate lenses outcropping on its sides (fig. 8). Most teeth and bones of small mammals were recovered by screen washing of lenses of microcrystalline calcite nodule conglomerate. Approximately one ton

of conglomerate from locality 41365 yielded 450 mammal teeth. Washing of mudstone has been unproductive. Remains of larger mammals, animals the size of *Phenacodus matthewi* or larger, are usually found in float, and when found in place, are usually in mudstone. Finding more than a few scraps of a single individual is rare; finding any articulated bones is very rare. Three partial and mostly disarticulated skeletons (41377-1, *Caenolambda* sp.; 41217-1, *Titanoides zeuxis;* 41364-1, *Psittacotherium* or *Lampadophorus)* have been found in place in mudstone, however. The pattern of occurrence and indications of pre-burial weathering (p. 40) indicate that most of the bones recovered from mudstone are the remnants of corpses normally accumulated on the Paleocene ground surface between sedimentary episodes. Teeth of crocodilians, gar scales, turtle shell, unionid shells, and steinkerns of small gastropods are also locally common.

Organic structures present, aside from animal remains, include silicified wood, burrows, coprolites, and ?charophytes. Large silicified logs are locally common, particularly in sandstone 4 (fig. 11). Cylindrical holes with bluntly rounded ends in sandstones and nodules, most from 0.5 to 1 centimeter in diameter, are probably the burrows of small invertebrates. Coprolites, recognized by their form, are occasionally found at Joe's Bonebed. Hollow spheres of calcite averaging 0.1 millimeter in diameter, seen in some of the sandstone, may be the calcified portion of oögonia of green algae.

Many of the fossils are encased in crusts. Spherulitic crusts of barite or calcite coat some bones, particularly bones from Ray's Annex and Ray's Bonebed. The porous bones served as channels for mineral-laden ground water and as centers of precipitation in the mudstone. Perhaps release of sulphur compounds as organic matter decayed triggered precipitation of the barium sulphate around bones. Crystal growth within many bones has disrupted their internal structure and fragmented their outer surface. Slippage in the mudstone is also responsible for some breakage. Encrustations of microcrystalline calcite nodular material on bone are common at many levels. Fortunately, crusts often leave fossil teeth exposed, probably because the smooth impermeable enamel did not provide effective

centers of precipitation. Crusts of gypsum occur on the surface of some fossil wood. The decaying wood may have provided sulphur compounds for the formation of the sulphate.

Description of Fossil Localities

Precise information on the location of Black Peaks fossil localities is available at the Vertebrate Paleontology Laboratory, Balcones Research Center, Austin, Texas. The locality and stratigraphic position in the formation of all specimens which are discussed in Systematic Paleontology can be found by looking up their numbers in table 1. Distribution of mammals within the formation is given in figure 34.

Collecting localities have been given informal names. Joe:s Bonebed was named after my father, Joe Schiebout, who discovered it. Ray's Annex and Ray's Bonebed were named after Raymond M. Alf of Claremont, California, who discovered them. The Schiebout-Reeves Quarry was named by J. A. Wilson after me and after Scott Reeves, his student field assistant for the summer of 1968, who did part of the excavating.

SYSTEMATIC PALEONTOLOGY

My work with the fossils of the Black Peaks Formation has concentrated on the mammals, which are the best preserved and most abundant group found. The non-mammalian fossil fauna, both invertebrate and vertebrate, is, with the exception of the Crocodilia, scarce and fragmentary and, as yet, is not useful for correlation.

Class MAMMALIA
Order MULTITUBERCULATA

The most common multituberculate specimens from the Black Peaks Formation are isolated incisors, which I have not attempted to identify. The symbol M_b ("b" for blade) has been used throughout the following discussions instead of P_4 at the suggestion of R. E. Sloan (1972, pers. comm.), who has discovered evidence that the multituberculate blade is a molar. I have followed Sloan's (Van Valen and Sloan, 1966; Sloan, 1972, pers. comm.) taxonomy throughout. Several of the species discussed have been previously referred to other genera.

Family PTILODONTIDAE
Gregory and Simpson, 1926
Genus PTILODUS Cope, 1881
Ptilodus COPE, 1881, p. 921
Chirox COPE, 1884, p. 321

PTILODUS MEDIAEVUS Cope, 1881
Fig. 12; Table 3
Ptilodus mediaevus COPE, 1881, p. 921
Chirox plicatus COPE, 1884, p. 321
Ptilodus plicatus (Cope), GIDLEY, 1909, p. 614

Type. AMNH 3019, right M_b, from the Torrejonian, San Juan Basin, New Mexico.

Material referred. 41274-4, left M^1; 40147-42, left mandible fragment with P_3-M_b; -47, left M_1; -45, right M_2; -46, right M_2; 41365-687, left P^2; -354, right P^2; -786, right P^2; -790, left P^2; -59, right P^2; -141, right P^2; -62, right P^4; -153, anterior half of right P^4; -55, posterior half of right M^1; -86, right M^2; -285, right M^2; -445, left M_b with posterior edge broken; -142, anterior half of left M_b; -369, worn posterior end of right M_1; -181, left M_2.

Description. Measurements and cusp or serration numbers for *Ptilodus mediaevus* are given in table 2. Specimen 41365-62, P^4, has a strong anterolabial shelf bearing three very faint cuspules which were not listed as cusps in table 2. The height of the first serration above the anterior enamel base is 53 percent of the length of M_b of 40147-42, the only Black Peaks *Ptilodus* M_b for which this measurement can be made. The ratio of the length of 40147-42, M_b, to the estimated length of 40147-47, M_1, is approximately 2:1.

All of the upper premolars listed above as P^2 are four-cusped. *P. mediaevus* P^3 may have more than four cusps (Simpson, 1937a, p. 80). These Black Peaks upper premolars are similar enough to one another in size and form to be the same tooth; however, some of them may be P^3, which is a highly variable tooth in *Ptilodus* (Granger and Simpson, 1929, p. 627).

Discussion. The P^4 with rudiments of an external third cusp row and low, straight lateral profile and the proportionally large M_b with its long anterior edge are characteristic of the genus *Ptilodus* (Jepsen, 1940, p. 264). Sloan (1966, fig. 4) gives the three youngest described species of *Ptilodus* as the roughly contemporaneous Torrejonian *P. wyoming-*

ensis, P. montanus, and *P. mediaevus. P. wyomingensis, P. montanus, P. mediaevus,* and the Black Peaks *Ptilodus* are similar in size (table 3; Jepsen, 1940, p. 285, 288; Simpson, 1937a, table 9). The northern species, *P. montanus* and *P. wyomingensis,* have 13-15 serrations on M_b; *P. mediaevus* from New Mexico has a median of 12 serrations (Jepsen, 1940, p. 286). The strong anterolabial shelf of the Big Bend P^4 resembles that of *P. mediaevus* and is unlike that of *P. montanus* (Simpson, 1937a, p. 85) or *P. wyomingensis* (Jepsen, 1940, pl. II, fig. 2a). The single specimen of P^4 of *P. wyomingensis* which has been reported in the literature has the cusp formula 0:7:9 (Jepsen, 1940, p. 289), *P. montanus* has 9-10 cusps in the internal row, and *P. mediaevus* has 8 (Simpson, 1937a, pp. 80, 93) as the Black Peaks specimen probably has. The Black Peaks occurrence of *P. mediaevus* extends its range into the Tiffanian (p. 43).

Family ECTYPODONTIDAE
Sloan and Van Valen, 1965

Two of the Black Peaks ectypodontid multituberculates, *Ectypodus musculus* and *Parectypodus sloani,* are very similar in size (tables 4, 5). They were identified by their P^4s and M_bs. The distinctive M_bs of both species and the P^4s of *E. musculus* were found at Joe's Bonebed (fig. 34). The only specimen referable to *E. musculus* from eastern Tornillo Flat is 40147-40, and it is too badly broken to be referred without question. Both P^4s and M_bs of *P. sloani* were found on eastern Tornillo Flat. The Black Peaks collection includes a few P^1s and molars which could be referred to either of the two species on the basis of size. The assignment of these teeth to species is tentative.

Genus ECTYPODUS
Matthew and Granger, 1921
Ectypodus Matthew and Granger, 1921, p. 1
ECTYPODUS MUSCULUS
Matthew and Granger, 1921
Fig. 13 a-e; Table 4
Ectypodus musculus MATTHEW and GRANGER, 1921, p. 1

Type. AMNH 17373, upper jaw with P^3-P^4 and M^1, and other possibly associated parts of upper and lower dentition, from Mason Pocket, Tiffanian of Colorado.

Material referred. ?40147-40, broken anterior half of left M_b; 41365-222, left P^4; -195, left P^4; -70, left P^4 with posterior edge broken; -495, posterior half of left P^4; -288, posterior half of left P^4; -301, posterior half of right P^4; -143, anterior half of left P^4; -792, posterior half of right P^4; -494, posterior half of left P^4; -?182, posterior end of left M^1; -462, anterior half of left M_b; -459, broken anterior half of right M_b; -?695, right M_1; -?774, posterior half of left M_1; -?528, right M_2 with posterior edge broken.

Description. Measurements and cusp or serration numbers for *Ectypodus musculus* are given in table 4. P^4 is high-crowned and trenchant. The anterior slope is straight; the posterior slope is straight or slightly concave. The ultimate and penultimate cusps are similar in height, but the penultimate cusp is usually highest. Specimen 41365-462, the best preserved M_b, lacks a notch for P_3.

The molars may belong with *Parectypodus sloani* instead of *E. musculus. E. musculus* M_1 has 8:6 cusps, and M_2 has 5-6:2 cusps (Granger and Simpson, 1929, p. 655). Cusp formulas of the Black Peaks M_1 and M_2 differ slightly from both the *E. musculus* figures and from those for two species of *Parectypodus* which are fairly close in age and form to *P. sloani* (p. 11). *P. sinclairi* M_1 has 6-7:4 cusps, and M_2 has 4:2 (Simpson, 1937a, pp. 97-98). *P. laytoni* M_1 has the formula 7:4, and M_2 has the formula 3:2 (Jepsen, 1940, p. 300). The Black Peaks M_1 is approximately 20 percent shorter than the length for *E. musculus* M_1 given by Granger and Simpson (1929, p. 655). The molars were placed with *E. musculus* because of their fairly close resemblance to previously described and figured molars of *E. musculus* and because there is no way to be sure at present if and how *P. sloani* and *E. musculus* molars differ. More material will be needed to discover criteria for separating *P. sloani* from *E. musculus* molars.

Discussion. The lateral profile of the high-crowned trenchant P^4 and the lack of an anterior notch in M_b for P_3 is characteristic of *E. musculus* (Granger and Simpson, 1929, p. 654, fig. 36). The Big Bend *Ectypodus musculus* differs only slightly from *E. musculus* as previously described. The Big Bend P^4s are seven percent larger than the *E. musculus* P^4s described by Granger and Simpson (1929,

pp. 654, 655). Some P^4 specimens of *E. musculus* have two external cusps and some have only one as do the Big Bend specimens. Except for a single M_1 from the Bison Basin, Wyoming, which Gazin (1956a, p. 13) referred to cf. *Ectypodus musculus*, *E. musculus* has been reported previously only from Mason Pocket in Colorado.

Genus *PARECTYPODUS* Jepsen, 1930
Parectypodus JEPSEN, 1930, p. 120
PARECTYPODUS SLOANI n. sp.
Fig. 13 f-l; Table 5

Type. 41365-113, left M_b, from Tiffanian Joe's Bonebed, Black Peaks Formation, western Tornillo Flat, Big Bend National Park, Texas.

Etymology. This species is named for Dr. Robert E. Sloan in gratitude for his help in my study of the Black Peaks multituberculates. He generously made available to me much unpublished information.

Hypodigm. 40147-67, right P^1; -36, left P^4; -37, right P^4; -41, left P^4; -35, right cracked M_b; -39, lingual half of left M_b; 41365-286, right P^1; -775, right P^1; -184, right M_b with posterior edge broken; -467, worn right M_b; -449, right M_b with crest of blade broken off; -63, posterior end of right M_b.

Diagnosis. The M_b of *Parectypodus sloani* is 10-15 percent longer than that of *P. laytoni*. M_b of *P. sloani* has fewer serrations than *P. laytoni* but is similar in lateral profile. The P^4 of *P. laytoni* has five external cusps; *P. sloani* has one to three. *P. sloani* is similar to *P. sinclairi* in the number of serrations on M_b and in having few external cusps on P^4; however, they differ in lateral profile of M_b.

Description. Measurements and cusp or serration numbers for *Parectypodus sloani* are given in table 5. In addition to the cusps listed, 40147-36 has several very tiny cuspules on the labial face of the posterior half of the tooth. P^4 is high-crowned and trenchant. The anterior slope is straight; the posterior slope is straight or slightly concave. The ultimate cusp is lower than the penultimate and antipenultimate cusps. On 40147-36 the antipenultimate cusp is highest; on 40147-37 the penultimate cusp is highest. M_b has a notch for P_3. The height of the first serration of M_b is 50 percent or slightly more of the tooth length. The labial height of enamel at the an-

terior root is approximately 90 percent of the length of 41365-113. Unworn M_bs are almost perfect half-circles in lateral view. The fourth serration from the anterior edge is the highest serration above the line of maximum anterior-posterior length.

The three P^1s are placed with *P. sloani* instead of with *E. musculus* because they are similar in form to P^1 of *Parectypodus laytoni* as figured by Jepsen (1940, pl. III, fig. 2). The external cusp of P^1 of *E. musculus* lies even with a point midway between the two internal cusps (Granger and Simpson, 1929, p. 654). In the Black Peaks specimens and in *P. laytoni* the external cusp is almost as far posterior as the posterointernal cusp.

Discussion. The teeth described above fall within *Parectypodus* according to Sloan's (1966, p. 310) description of the genus. The Big Bend P^4 cusp formula is within Sloan's range for *Parectypodus* P^4. Sloan described P^4 as having a short, slightly concave posterior slope and, usually, having the antipenultimate cusp highest. Among the characters which Sloan used to define *Parectypodus* and which are seen in the Big Bend M_bs are: the height of the first serration above the anterior enamel base is more than 50 percent of the tooth length, the labial height of enamel at the anterior root is approximately the same or greater than the tooth length, and the third or fourth serration is highest above the line of maximum anteroposterior length.

The previously described species of *Parectypodus* which are most nearly contemporaneous with *P. sloani* are the late Torrejonian *P. sinclairi* and the middle Tiffanian *P. laytoni* (Van Valen and Sloan, 1966, fig. 5). The lateral profile of M_b of *P. sloani* closely resembles the profile of *P. laytoni*. Serrations of M_b of *P. laytoni* range from 12-14 with a mode of 12 (Jepsen, 1940, table 7); however, M_b of *P. sloani* has 10 serrations. The P^4 of *P. laytoni* has a cusp formula of 5:9 compared to 1-3:9 in *P. sloani*. Fewer external cusps occur in primitive *Parectypodus* species than in advanced species (Sloan, 1966, p. 310). The one *P. sloani* P^4 which has several tiny cuspules anterior to the external cusp row may indicate a trend in *P. sloani* toward development of more cusps. Structurally, *P. sloani* could be ancestral to *P. laytoni*. On the other hand, the older *P. sinclairi* which, like *P. sloani*, has few cuspules in the external row

of P^4 and which has 10-13 serrations on M_b (Simpson, 1937a, p. 98), differs considerably in M_b lateral profile. The *P. sinclairi* M_b has a posterior slope much longer than the anterior slope instead of almost equal slopes as in *P. sloani*. The similarities in serration and cusp number of *P. sinclairi* and *P. sloani* are interpreted to be common primitive characters and do not necessarily indicate close relationship.

Genus *MIMETODON* Jepsen, 1940
Mimetodon JEPSEN, 1940, p. 314
MIMETODON SILBERLINGI (Simpson),
1935
Fig. 13 m-p
?Ectypodus silberlingi SIMPSON, 1935, p. 226
Mesodoma silberlingi (Simpson), VAN VALEN
and SLOAN, 1966, p. 270

Type. USNM 9798, broken left mandible with I and M_b-M_2, from Gidley Quarry, Torrejonian of Montana.

Material referred. 40147-34, left M_b; -64, broken posterior edge of left M_b; 41365-53, posterior half of right P^4; -641, posterior half of right P^4; -311, broken posterior half of right M_b.

Description. The P^4 scraps have a slightly concave posterior slope. The posterior slope is less steeply inclined than in P^4 of *E. musculus* or *P. sloani;* the tooth must have been lower crowned than P^4 of these species. The ultimate, penultimate, and antipenultimate cusps are very nearly the same height. The single whole M_b, 40147-34, has a notch for P_3. It is 3.4 mm in anteroposterior length and 1.2 mm in width. The height of the first serration above the anterior enamel base is 40 percent of the total tooth length. The labial height of enamel at the anterior tooth root cannot be measured accurately because the enamel is chipped at the base. The M_b has a low lateral profile (fig. 13). It has 11 serrations.

Discussion. The low lateral profile of M_b rules out its being placed with any of the other Big Bend multituberculates, and the lateral profile of P^4 is lower than that of other Big Bend multituberculates except the much larger *Ptilodus.* P^4s of *M. silberlingi* have not previously been discovered (Sloan, 1972, pers. comm.).

Sloan (1972, pers. comm.) now places the species previously called *?Ectypodus silberlingi* (Simpson, 1935c, 1937a; Jepsen, 1940) and *Mesodma silberlingi* (Van Valen and Sloan, 1966, fig. 5) in the genus *Mimetodon.* The single *M. silberlingi* M_b, PU 14539, described by Jepsen (1940, p. 293) is 3.2 mm long and has 11 serrations. Specimen 40147-34 falls within the range of *M. silberlingi* in size and form (Sloan, 1972, pers. comm.). *M. silberlingi* has previously been reported from the Torrejonian (Van Valen and Sloan, 1966, fig. 5). The Black Peaks occurrence extends its range into the Tiffanian.

Genus *NEOPLAGIAULAX* Lemoine, 1882
Neoplagiaulax LEMOINE, 1882, p. 1011
NEOPLAGIAULAX DOUGLASSI (Simpson),
1935
Fig. 14a-b
?Ptilodus douglassi SIMPSON, 1935, p. 225
Mimetodon douglassi (Simpson), VAN VA-
LEN AND SLOAN, 1966, p. 270

Type. USNM 9795, right mandible with M_b-M_2, from Gidley Quarry, Torrejonian of Montana.

Material referred. 40147-15, cracked right M_b with roots and posterior edge broken off; -38, cracked right M_b with anterior part of crest broken off; -66, anterior half of right M_b.

Description. Specimen 40147-38 is approximately 5.6 mm long, and 40147-15 is approximately 6.4 mm long. These measurements should be fairly close to the anteroposterior lengths of the teeth before they were broken. The blades have a notch for P_3. Eleven serrations can be counted on 40147-15; that is probably the correct figure for the unbroken tooth. The height of the first serration above the base of the enamel on 40147-15 is 3.3 mm. I estimate that if 40147-15 were not broken, the height of the first serration would be slightly under 50 percent of the total length of the tooth. The third or fourth serration from the anterior edge on 40147-15 is the serration highest above the line of greatest anteroposterior length.

Discussion. The two M_bs referred to *N. douglassi* are smaller than M_b of the Black Peaks *Ptilodus mediaevus* and have one less serration (table 3). They fall within the size range of *"?Ptilodus"* [*Neoplagiaulax*] *douglassi* given by Simpson (1937a, table 14). Sloan once placed the species *"P."* [*Neoplagiaulax*]

douglassi in *Mimetodon* (Van Valen and Sloan, 1966, fig. 5); he now places it in *Neoplagiaulax* (Sloan, 1972, pers. comm.). In addition, he believes that *N. douglassi* may be ancestral to Russell's (1964, p. 32) *Neoplagiaulax* sp. *A* from the Thanetian of France. The anterior edge of 40147-15 is similar in lateral profile to the anterior edge of USNM 9795, "*Ptilodus*" [*Neoplagiaulax*] *douglassi* (Simpson, 1937a, fig. 9) and is more convex than the anterior edge of Big Bend *P. mediaevus* M_b. Simpson (1937a, table 14) lists the number of serrations of three M_bs of *N. douglassi* as 13, two more than I estimate that 40147-15 had. *N. douglassi* has previously been reported only from the Torrejonian (Van Valen and Sloan, 1966, fig. 5). The Black Peaks occurrence extends its range into the Tiffanian.

Genus *MESODMA* Jepsen, 1940
Mesodma JEPSEN, 1940, p. 267
MESODMA sp.
Fig. 14c

Material referred. 40147-74, worn right M_2.

Description. The tooth is 1.2 mm in anteroposterior length and 1.0 mm in width. It has four cusps in the labial row and two in the lingual row.

Discussion. The smallest multituberculates from the Black Peaks Formation, aside from this specimen, are *Ectypodus musculus* and *Parectypodus sloani*. *E. musculus* M_2, reported as 1.4 mm by 1.1 mm, is almost as small as 40147-74, but its cusp formula is 5-6:2 (Granger and Simpson, 1929, p. 655). The single other small Big Bend M_2, 41365-528, tentatively referred to *E. musculus*, has a cusp formula of 4:3. It is not possible to prove that 40147-74 does not belong to *P. sloani*; however, 40147-74 resembles closely M_2 of a small undescribed species of *Mesodma* from Gidley Quarry which R. E. Sloan is studying.

Order INSECTIVORA

Aside from the two teeth described below, one assigned to *?Palaeictops* and one assigned to *Jepsenella*, only small fragments of insectivore teeth are available from the Black Peaks Formation. Upper insectivore teeth are represented in the collection only by scraps of lingual sides, two of which are figured (fig. 19f-g). These scraps are too large to belong

to *Jepsenella*. Although the scraps are not generically identifiable, the range of variation among them suggests that the list of insectivores from the Black Peaks Formation is far from complete.

Family LEPTICTIDAE Gill, 1872
Genus *?PALAEICTOPS* Matthew, 1899
?PALAEICTOPS sp.
Fig. 14d; Table 6

Material referred. 41365-326, right M_2 without metaconid.

Description. The paraconid is small and low on the trigonid, slightly lingual to the anteroposterior midline. The trigonid is high with a sharp protoconid. The talonid is low and slightly narrower than the trigonid. The posterior rim of the talonid basin is worn, but the entoconid remains distinct. No mesoconid is present.

Discussion. Specimen 41365-326 is a leptictid insectivore which fits Van Valen's (1967) criteria for the genera *Palaeictops, Prodiacodon,* and *Diacodon*. Van Valen (1967, table 5) gave no differences that can be applied to 41365-326 in order to identify to which of these three genera it belongs. *Palaeictops* ranges from the early Paleocene to middle Eocene, *Prodiacodon* has been reported from the middle Paleocene, and *Diacodon* ranges from the middle Paleocene to the early Eocene (Van Valen, 1967, p. 232).

Specimen 41365-326 is similar in size and form to *Diacodon pearcei* from the Bison Basin Tiffanian fauna of Wyoming, except that *Diacodon* has a proportionally narrower talonid (Gazin, 1956a, p. 17, pl. I, fig. 6). According to Gazin (1956a, p. 17), the only characteristic which separates *Diacodon* from *Palaeictops* and *Prodiacodon* which can be applied to 41365-326 is that the talonids of *Diacodon* are proportionally narrower than those of *Palaeictops* or *Prodiacodon*. Three or four undescribed species of *Palaeictops* have been discovered from the early and middle Paleocene (Van Valen, 1967, p. 232). The only Paleocene species of *Palaeictops* yet described is *P. septentrionalis* from the late Paleocene Cochrane locality in Alberta, Canada. The paratype of *P. septentrionalis*, an M_1 or M_2, is about the same size as 41365-326, but the damage to the posterior rim of the 41365-326 talonid makes it impossible to de-

termine whether or not it had a strong conical hypoconulid like that of the *P. septentrionalis* specimen described by Russell (1929, p. 174). *P. septentrionalis* also has a narrower talonid. Further description of this Big Bend insectivore will await more and better material.

Family APATEMYIDAE Matthew, 1909
Genus *JEPSENELLA* Simpson, 1940
Jepsenella SIMPSON, 1940, p. 186
JEPSENELLA undescribed species
Fig. 14e; Table 6

Material referred. 41365-269, right M_2.
Description. Specimen 41365-269 has a high trigonid with a subinternal paraconid. The paracristid forms a squared anterolabial corner, but there is no fourth trigonid cusp. The metaconid is a little taller than the protoconid. The deep talonid basin is completely enclosed by an almost smooth cristid obliqua and posterior rim. The posterior talonid rim is slightly worn. There is no talonid notch; the hypoconulid is faint and set slightly labial to the transverse midpoint. There are no cingula on the tooth.
Discussion. Specimen 41365-269 is similar in form to M_2 of AMNH 35292, type of *Jepsenella praepropera*, in direct comparison and in comparison with McKenna's (1963) detailed descriptions. The trigonid of 41365-269 is a little lower than that of the *Jepsenella praepropera* type, but higher than the trigonids in *Labidolemur* (McKenna, 1963, fig. 2; West, 1972, fig. 1). The greater trigonid height of *Jepsenella* is the only one of the characteristics separating *Jepsenella* and *Labidolemur* (McKenna, 1963, p. 18) which can be determined from 41365-269. The Big Bend specimen is closer to *Jepsenella*. The paraconid of M_1 of AMNH 35292 had been destroyed before I saw the specimen. McKenna (1963, p. 16) stated that the paraconid must have been more lingually placed in M_1 than in M_2 and that M_1 has a faint trace of a fourth trigonid cusp at the anterolabial edge which M_2 lacks. Thus 41365-269 is probably an M_2. Szalay (1968c, fig. 4) has a drawing of AMNH 35292 with the paraconid of M_1 reconstructed from AMNH 89515 from Swain Quarry, Wyoming, showing the difference in paraconid position.
Jepsenella praepropera is the only species which has previously been assigned to *Jepsen-*

ella, and it is known from only two localities, Gidley Quarry in Montana and Swain Quarry in Wyoming. The differences in size (table 6) suggest that the Big Bend specimen represents a new species, but until more specimens, both of the northern and the Big Bend *Jepsenella,* are available so that size ranges can be estimated, I will not assign a new name. *Jepsenella* has been considered ancestral to the early Tiffanian *Labidolemur* (West, 1972, p. 11), one species of which occurs in Mason Pocket in Colorado (Matthew and Granger, 1921), and the other species of which occurs at the Bison Basin Saddle locality in Wyoming (West, 1972). More specimens will be needed before the evolutionary position of the Big Bend apatemyid, which is smaller and younger than previously known *Jepsenella* and intermediate between *Jepsenella* and *Labidolemur* in trigonid height, can be evaluated.

Order PRIMATES
Family PAROMOMYIDAE Simpson, 1940
Genus *PHENACOLEMUR* Matthew, 1915
Phenacolemur MATTHEW, 1915, p. 479
Ignacius MATTHEW and GRANGER, 1921, p. 5
PHENACOLEMUR FRUGIVORUS
(*Matthew and Granger*), 1921
Fig. 15a-c; Table 7
Ignacius frugivorus MATTHEW and GRANGER, 1921, p. 5
Phenacolemur frugivorus (Matthew and Granger), SIMPSON, 1935, p. 19
Phenacolemur fremontensis, GAZIN, 1971

Type. AMNH 17368, left maxilla with P^2 and P^4-M^2, from Mason Pocket, Tiffanian of Colorado.
Material referred. 41365-682, right P^4; -186, right M^2; -19, worn left M^2; -237, right ?M_1 talonid.
Description. Specimen 41365-682 is almost square, with the posterolingual tooth corner slightly more lingually extended than the protocone. A faint crest extends from the posterolabial side of the protocone to the posterolingual side of the paracone. Specimen 41365-186 is shorter anteroposteriorly than 41365-682. Specimen 41365-186 has a strong postprotocrista; it lacks an ectocingulum, but does have a very small conule in the mesostyle position. On 41365-19 the paraconid lies as far lingual as the metaconid and is partly con-

fluent with it. The trigonid and talonid of 41365-19 are equally broad transversely.

Discussion. Of the five previously named species of *Phenacolemur, P. frugivorus, P. pagei, P. fremontensis, P. praecox,* and *P. jepseni,* the smallest and earliest occurring, and thus the most likely to be comparable to the Black Peaks specimens are *P. fremontensis, P. frugivorus,* and *P. pagei.* Differences between *P. frugivorus* and *P. pagei* (Simpson, 1955, pp. 421-423) which can be applied to the Black Peaks material include: the teeth are smaller in *P. frugivorus;* M^1-M^2 in *P. frugivorus* have a weak external cingulum on the metacone; they lack any trace of a mesostyle, while M^1-M^2 on *P. pagei* have a well-developed external cingulum with a spur in the mesostyle position; and M_1-M_2 are more nearly equidimensional in *P. pagei* than in *P. frugivorus.* Differences of *P. fremontensis* compared with *P. frugivorus* (Gazin, 1971, pp. 32-33) which can be applied to the Black Peaks specimens are: lower molars of *P. fremontensis* are slightly shorter and relatively narrower than those of *P. frugivorus;* and the trigonid and talonid of M_2 of *P. fremontensis* are almost equal in width.

Specimen 41365-186 resembles *P. frugivorus* rather than *P. pagei* in the lack of a well-developed ectocingulum and of a spur in the mesostyle position. The differences in size and proportion of 41365-19 and M_2 of previously described *P. frugivorus* and *P. fremontensis* do not appear to be significant (table 7). Specimen 41365-19 is proportionally wider than M_2 of *P. fremontensis.* The trigonid and talonid of 41365-19 have equal width, a *P. fremontensis* character according to Gazin (1971, p. 33).

Direct comparison of Big Bend specimens with some of the material used by Simpson (1955, pp. 421-422) to characterize *P. frugivorus* revealed few differences. Specimen 41365-19 is similar in form but slightly smaller than M_2 of AMNH 33987, *P. frugivorus* from the Scarritt Quarry, Montana. Specimen 41365-186, an M_2, is slightly smaller and has a very faint mesostyle which M^2 of AMNH 17368, type of *P. frugivorus,* lacks, but it is otherwise similar. Specimen 41365-682 and P^4 of AMNH 17368 both lack a postprotocrista. The P^4 of AMNH 17368 has a crest running from the paracone tip to the transverse midpoint of the tooth on the preproto-

crista. This crest is lacking on 41365-682. Specimen 41365-682 has a faint crest extending from the posterolabial side of the protocone to the posterolingual side of the paracone. This crest is absent on P^4 of AMNH 17368. Specimen 41365-682 is also longer than P^4 of AMNH 17368. No P^4 is available for *P. fremontensis* (Gazin, 1971, p. 32), and too few specimens of P^4 of *P. frugivorus* are available to assess variability.

Most of the characters used by Gazin (1971, pp. 31-33) to distinguish *P. fremontensis* from *P. frugivorus* can be determined from P_4, M_2, and M^2. Several of these characteristics of M_2 and M^2 can be found in specimens of *Phenacolemur* which are otherwise referable to *P. frugivorus.* Too few measurements and specimens are available for statistical comparison of the two species, but the size differences do not appear significant. One of the chief differences between *P. fremontensis* and *P. frugivorus,* according to Gazin (1971, p. 32), is that P_4 is much smaller in *P. fremontensis.* The difference in P_4 length alone is not, however, sufficient to distinguish *P. fremontensis* and *P. frugivorus* (table 7).

The oldest occurrence of *P. frugivorus* reported by Russell (1967) is at Gidley Quarry and the youngest is at Scarritt Quarry (fig. 35). It is possible that Russell's (1967, p. 70) listing of *P. frugivorus* from Gidley Quarry is an error, since the original reference (Simpson, 1937a) does not include *P. frugivorus* in faunal lists from Gidley Quarry, and since Simpson's (1955, p. 421) discussion of its distribution lists only Tiffanian occurrences. The oldest published occurrence is in the Shotgun fauna and is reported as *P.* cf. *frugivorus,* occurring with *P. fremontensis* (Gazin, 1971, pp. 31-33).

Genus *NAVAJOVIUS* Matthew and Granger, 1921

Navajovius MATTHEW and GRANGER, 1921, p. 5

NAVAJOVIUS KOHLHAASAE
Matthew and Granger, 1921
Fig. 15e-i; Table 8

Type. AMNH 17390, left mandible with I and P_2-M_3, left maxillary with P^4-M^3, from Mason Pocket, Tiffanian of Colorado.

Material referred. 40147-62, maxilla fragment with left M^2 and alveoli of M^1, part of P^4 and M^3; 40537-100, lingual half of right

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M^1 or M^2; -127, right M_1; 41365-340, left M_1; -500, right M_2; -636, right M_2; -697, left M_2.

Description. Specimen 40147-62 has a small cuspule on the anterolingual side of the protocone at the same height as the end of the precingulum but separate from it. The precingulum runs labially one-half the width of the tooth. The hypocone is distinct and is separated from the protocone by a faint groove on the lingual face. It is not connected to the protocone tip. It lies labial to the lingual edge of the tooth, so that the lingual side of the tooth is gently rounded, not squared. The tooth is not anteriorly skewed, that is, the protocone lies only slightly anterior to the position of the midpoint between paracone and metacone. A metaconule with premetaconule and postmetaconule cristae and a paraconule with preparaconule crista are present. The paracone is larger than the metacone and the ectocingulum is weak. A small metastyle is present. Specimen 40537-100 is very similar to the lingual half of 40147-62, except 40537-100 lacks the small cuspule on the anterolingual side of the protocone.

Talonids of the lower molars are wider than trigonids. Lower molars lack precingula, and paraconids are small and set low on the trigonids. Paracristids are angulate at the anterolabial corner; paraconids are set more medial and anterior in M_1 than in M_2. Protoconids are larger than metaconids. Faint labial cingula are present, but they do not extend across the labial side of the protoconids. The cristid obliqua joins the trigonid at approximately the level of the midpoint of the protoconid. Specimen 41365-697 has a small mesoconid; the rest lack mesoconids. Talonid basins are deep. Entoconids are distinct cusps set at the posterolabial tooth corners. Hypoconulids are not conical; they are sections of the postcristid, nearer the entoconid than the hypoconulid, set off by notches formed by the shallow grooves of the talonid basins. There are no postcingulids.

Discussion. The phylogenetic position of the genus *Navajovius* has long been in doubt. The latest worker to deal with the question (Szalay, 1972, pp. 9-10) placed the genus in Paromomyidae. Several features of the small Big Bend primate molars indicate that they belong in the genus *Navajovius*, instead of with small plesiadapids or paromomyids such as

the Torrejonian Palaechthonini to which *Navajovius* may be related (Szalay, 1968a, pp. 26-27). The paracristid shape and hypoconulid position described for the Black Peaks specimens are distinctive features of *Navajovius* (Szalay, 1969, p. 276). The Palaechthonini, *Palaechthon, Palenochtha,* and *Plesiolestes,* have skewed upper molars in which the protocone is lined up with the paracone or nearly so (Szalay, 1968a, pp. 27-28). *Palenochtha minor* is the only species of these three genera small enough to be comparable in size to these Big Bend tiny primates. Gazin (1971, pp. 24-26) gave a detailed comparison of *Palaechthon woodi* and *N. kohlhaasae.* The smallest plesiadapid is *Pronothodectes matthewi* (Gazin, 1971, p. 21). Although the upper molars of *Pronothodectes* are not skewed, all lack hypocones (Gidley, 1923, p. 12), and none small enough to be comparable to the Big Bend specimens are known. The length of M_2 of *Pronothodectes matthewi* is approximately 60 percent greater than the length of 41365-636. Russell (1964, p. 125) considered *Berruvius* from Cernay in France to be closely comparable to *Navajovius.* Szalay (1972, p. 10) believed that the genera are synonymous.

Too few specimens either of the Big Bend *Navajovius* or of previously described *Navajovius* are available for the ranges of variation to be estimated. Only three specimens of *N. kohlhaasae* have been described, and all three are from the Tiffanian of Colorado (Szalay, 1969, pp. 278-279). The only other species of *Navajovius* is the smaller *?Navajovius mckennai,* a poorly known species based on a single fragment with P^3-M^1 from the early Eocene Almagre facies of the San Jose Formation of New Mexico (Szalay, 1969, p. 280).

Direct comparison with the three previously described specimens of *N. kohlhaasae* revealed only small differences, none of which warrant placing the Black Peaks specimens in a new species. The Big Bend specimens are slightly smaller than the previously reported *N. kohlhaasae* specimens (table 8; Szalay, 1969, table 19). The lowers are very close in form to those of AMNH 17390; specimen 40537-127 is an exact match in form for M_1 of AMNH 17390. The only difference between M^2 of AMNH 17390 and 40147-62 is that the metacone of 40147-62 is slightly more lingual. The presence on western Tornillo Flat of an upper molar fragment similar to the upper

molar from eastern Tornillo Flat helps make the association of the Black Peaks upper and lower teeth from different localities in one species, *N. kohlhaasae,* reasonable.

Family PICRODONTIDAE Simpson, 1937
Genus *?ZANYCTERIS* Matthew, 1917
?ZANYCTERIS sp.
Fig. 15d

Material referred. 41365-145, left M_2 trigonid.

Description. The paraconid in 41365-145 lies lingual to the tooth midpoint, nearer the metaconid than the protoconid, and the paracristid forms a semicircle between protoconid and paraconid. The gently sloping posterior trigonid wall is wrinkled.

Discussion. Only two genera and two species have been described for the Picrodontidae, *Picrodus silberlingi* from the Torrejonian of Montana and Wyoming and the early Tiffanian of Wyoming and *Zanycteris paleocenus* from the Tiffanian of Colorado (Szalay, 1968b). Specimen 41365-145 agrees with Simpson's (1937a, p. 138) description of *Picrodus silberlingi* M_2 trigonid. *P. silberlingi* is the only picrodontid for which M_2 is known. No lower teeth of *Zanycteris paleocenus* have yet been reported (Szalay, 1968b, p. 25). The type of *Z. paleocenus* came from Mason Pocket, Colo. Specimen 41365-145 was probably at least twice as large as M_2 of any previously described picrodontid. Comparison of Szalay's (1968b) size data on upper teeth shows that *Z. paleocenus* and *P. silberlingi* did not differ much in size. Szalay (1968b, table 1) gave the range for length of M_2 of *P. silberlingi* from Swain Quarry in Wyoming as 1.5-1.6 mm. Specimen 41365-145 measures 1.2 mm from the anterior edge of the tooth to the tip of the metaconid. More material is needed to determine if the Black Peaks picrodontid can be placed in an existing genus or species.

Family PLESIADAPIDAE Trouessart, 1897
Genus *PLESIADAPIS* Gervais, 1877
Plesiadapis GERVAIS, 1877, p. 76
Nothodectes MATTHEW, 1915, p. 482
PLESIADAPIS GIDLEYI (Matthew), 1917
Figs. 16b-k, 17; Tables 9, 10
Nothodectes gidleyi MATTHEW, 1917, p. 832
Plesiadapis gidleyi (Matthew), SIMPSON, 1935, p. 3

Type. AMNH 17170, upper and lower jaws with most of worn dentition, from Mason Pocket, Tiffanian of Colorado.

Material referred. 40537-37, left toothless mandible fragment; 41365-815, distal end of upper right I; -274, distal end of upper left I; -327, left P^3; -692, right P^4; -443, right P^4; -73, right M^1; -245, left M^1; -183, right M^2; -150, left M^2; -403, worn left M^2; -463, left M^3; -31, right M^3; -833, proximal end of lower right I; -717, proximal end of lower left I; -90, left P_4; -525, left P_4; -291, left P_4; -173, left M_1; -791, worn left $?M_1$; -399, left M_2; -129, left M_2; -191, left $?M_1$; -541, worn right M_3; 41366-77, right mandible with P_4-M_3 and roots of I and P_3.

Comments. Only whole teeth in good condition are listed above. About 30 strongly worn or broken teeth from locality 41365 (Joe's Bonebed Conglomerate) are identifiable as belonging to this primate but are not listed.

Description. Upper incisors have a large lateral cusp and a very small cusp on the medial side distal to the level at which the lateral cusp branches off. P^3 has paracone and metacone confluent. The paracone is larger than the metacone and lies directly labial to the protocone position. The tooth has a faint precingulum, a preprotocrista, and a postcingulum, but only a weak ectocingulum which does not extend across the labial side of the paracone. There is a small cusp on the anterolabial corner, and a small crescentic cusp, perhaps the protoconule, on the lingual side of the paracone. P^4 is similar except its ectocingulum is stronger, its anterolabial cusp is weaker, and it has no distinct paraconule, only a rugose swelling on the lingual side of the paracone. Upper molars are not skewed. They have precingula and strong postcingula which connect to the tip of the protocone. They have paraconules and metaconules and strong mesostyles which connect the ectocingula to the crest between the paracone and metacone. The postcingulum extends further posteriorly on M^2 than on M^1, making the protocone area of M^2 longer anteroposteriorly. On M^3 the postcingulum extends further posteriorly than in M^1 or M^2, and a stylar shelf and ectocingulum are not present on the metacone.

The posterolateral cusp on lower incisors is small but distinct. Specimen 40537-37 had a large two-rooted P_3, but no alveolus for P_2. Specimen 41366-77 also had a large two-root-

ed P$_3$. Damage anterior to P$_3$ makes it impossible to tell if a P$_2$ was present. Both 40537-37 and 41366-77 lack a diastema between the large lower incisor and P$_3$, and the jaws are short and deep. Specimens of P$_4$ show no trace of paraconid or metaconid. P$_4$ has a small heel with a hypoconid, an entoconid, and a faint cristid obliqua. A ridge runs down the posterolingual and the posterolabial side of the protocone from its point. M$_1$ and M$_2$ have a strong paracristid and a weak protocristid. The paraconid is slightly smaller than the metaconid. On M$_2$, the paraconid is more medial and less confluent with the metaconid. Small mesoconids are present on most lower molars and, where absent, have probably been removed by wear. Talonid basins are deep and furrowed, with a deep talonid notch. Trigonids are proportionally narrower than talonids in M$_1$ compared to M$_2$. M$_1$ and M$_2$ either lack a hypoconulid or have a crescentic portion of the postcristid set off by furrows in the talonid basin. Specimen 41365-191 is not only smaller than any other lower molar, but it also has a shallower talonid notch and less distinct furrows in the talonid basin. The trigonid of M$_3$ is similar to that of M$_2$. The hypoconid of M$_3$ is distinct, but other cusps on the postcristid are not. The posterior lobe is transversely broad.

Discussion. The North American Tiffanian species of *Plesiadapis* are: *P. gidleyi, P. jepseni, P. fodinatus, P. anceps, P. farisi,* and *P. rex.* Differences separating some of these species are minor; some of the species may be synonymous. *P. jepseni, P. anceps,* and *P. gidleyi* differ little in size (table 8). Gazin (1956a, pp. 22, 24; 1956b, p. 709) and Dorr (1958, p. 1227) considered *P. jepseni-P. anceps-P. rex* to be a subgeneric group characterized by a long slope on the labial side in the lower molars, and *P. gidleyi-P. farisi-P. fodinatus* to be a group characterized by a short slope. The mesostyle is weak or absent on upper molars of *P. jepseni* (Gazin, 1956a, p. 23) and absent in *P. anceps* (Simpson, 1936b, p. 19). Upper molars of *P. rex* have not been described in the literature, and so few lower teeth have been described that the position of this species is quite uncertain (Simpson, 1937a, pp. 168-169). *P. gidleyi* (Simpson, 1935b, p. 4), *P. farisi* (Dorr, 1958, p. 79), and *P. fodinatus* (Jepsen, 1930, pl. 5) have molar mesostyles. The Black Peaks plesiadapids resemble the *P. gidleyi-P. farisi-P. fodinatus* group in tooth form.

The Black Peaks lower molars fall within the size ranges for *P. gidleyi* lower molar measurements given by Simpson (1935b, pp. 6-7), although P$_4$ is larger in the Big Bend specimens than in *P. gidleyi* from Mason Pocket in Colorado (table 10). *P. fodinatus* is significantly larger than *P. gidleyi* in length of lower molars (table 10; Simpson, 1935b, p. 7). *P. farisi* lies between *P. gidleyi* and *P. fodinatus* in size according to Dorr (1958, p. 1227).

The Big Bend plesiadapoid primate teeth fit Simpson's (1935a, pp. 2-6) description of *P. gidleyi* teeth. Direct comparison with the type specimen of *P. gidleyi* and other AMNH *P. gidleyi* specimens revealed no significant differences in form of the teeth. The earliest occurrence yet reported of *P. gidleyi* is in the late Torrejonian or early Tiffanian Battle Mountain fauna and the latest occurrence is in the Tiffany fauna (Russell, 1967).

The two mandibles, 41366-77 and 40537-37, differ from previously described *P. gidleyi,* and resemble the *P. jepseni-P. anceps-P. rex* subgeneric group, or even *Chiromyoides,* in ways which may be significant (Russell, 1964, pp. 81-84, 119). P$_2$ is lacking in 40537-37 and probably lacking in 41366-77. The lack of a diastema between P$_3$ and the incisor, the shortness and depth of the mandibles, and the size and orientation of the lower incisor, which is larger and less procumbent than that of previously described *P. gidleyi* (Simpson, 1935a, pp. 2, 4), are characteristics of the subgenus *Plesiadapis (Menatotherium)* (Szalay, 1972, p. 17) as contrasted to *Plesiadapis (Plesiadapis)* in Russell (1964, pp. 81-84). Gingerich (1973) is reviewing the Plesiadapidae and has recently described a North American species of *Chiromyoides,* one upper incisor of which has been recovered from the Black Peaks Formation.

Genus *CHIROMYOIDES* Stehlin, 1916
Chiromyoides Stehlin, 1916, p. 1489
CHIROMYOIDES CAESOR Gingerich, 1973
Chiromyoides caesor Gingerich, 1973, p. 2
Fig. 16a

Type. PU 21575, left upper incisor, from Croc Tooth Quarry, late Paleocene of Wyoming.

Material referred. 41365-826, right upper incisor.

Description. The cusps are much thicker, blunter, and more lingually directed and the medial cusp is larger on 41365-826 than on Big Bend *Plesiadapis* upper incisors.

Discussion. Comparison with a cast of PU 21575 reveals no significant differences. Specimen 41365-826 is less worn. *C. caesor* also occurs with *P. gidleyi* at Mason Pocket, Tiffanian of Colorado (Gingerich, 1973, p. 2).

Order TAENIODONTA
Family STYLINODONTIDAE Marsh, 1875
Genus *PSITTACOTHERIUM* Cope, 1822, or
LAMPADOPHORUS Patterson, 1949
Fig. 18

Material referred. 40147-3, fragment of incisor; fragment of canine, right ?P^3; -7, edentulous right mandible fragment; 40148-2, left ?M^1; 40535-86, incisor fragment; 40536-119, left ?P^2; 40537-26, left ?M^1; -33, left ?M^1; -61, right ?M^1; -140, skull fragments in concretion and part of right upper canine; -68, claw; 41366-1, maxillary fragments with roots of premolars and molars; 41366-73, upper incisor roots in jaw fragment; 41364-1, skull fragments with both canines and one incisor, sockets for six left cheek teeth and associated bone fragments.

Comments. Approximately half of specimen 40147-3a has been lost since it was figured by Wilson (1967, fig. 108c). Specimen 40148-2 was described by Wilson (1967, p. 159) as from eastern Tornillo Flat; however, its number indicates a western Tornillo Flat locality. There is no way to be sure from which locality it came.

Description. On all three of the incisors the enamel covers only the anterior side of the tooth. The enamel on upper canines of 41364-1 and 40537-140 does not extend onto their lingual faces. A shallow groove runs along the anterolabial side of these canines. The only Big Bend specimen on which the canine root area can be examined is 41364-1. The root extends at least as far posteriorly as the position of M^1, but the enamel thins to a feather edge above the socket of P^4. Specimen 40536-119, the anteriormost available premolar, has a ridge with a few cuspules on it connecting the protocone and paracone on the posterior side. Specimen 40147-3 has ridges connecting the protocone to the anterior and posterior sides of the base of the paracone. The only cuspule on the ridges is in the hypocone position, but other cuspules may have been worn off. Specimens 40537-26, 40537-33, and 40537-61 are similar to one another. All three have a deep median basin and cuspule-bearing ridges connecting the protocone to the base of the paracone and to the base of the small metacone, which is partly confluent with the paracone. Specimen 40537-26 has only small cuspules in the hypocone position, while in 40537-33 and 40537-61 the cuspule in the hypocone position is the largest of the cuspules on the posterior ridge. These three teeth, when strongly worn, would probably look like 40148-2, which is worn below the level of the basin, leaving the posterolabial side a high rim and the rest of the crown flat. On all cheek teeth the enamel extends in a band much farther down the lingual side of the protocone than on the rest of the tooth. All of the cheek teeth except 40148-2 show two small prongs of enamel extending downward on the labial side. The roots are broken off all cheek teeth. All of them show a shallow vertical groove on the labial side below the enamel, indicating that there might have been some division of the root under the paracone and metacone. Faint grooves on the sides of 40536-119, 40537-61, and 40537-33 indicate that there may have been some transverse division of their roots. The only available socket which gives any information on root shape is the socket of P^4 on 41364-1, which shows that there was some division of the labial portion of the root (fig. 18a). The sockets on 41364-1 show that P^1 was the shortest-rooted of the premolars and that P^2 was longer-rooted than any other cheek tooth.

Discussion. No Tiffanian taeniodonts have been reported previously. *Psittacotherium* has been reported from the Torrejonian and *Lampadophorus* from the Clarkforkian (Russel, 1967). Patterson (1949b, p. 243) considered *Lampadophorus* to be a descendant of *Psittacotherium*. None of the characteristics which he used to distinguish *Psittacotherium* and *Lampadophorus* can be applied unambiguously to the Black Peaks material. Progressive characteristics of *Lampadophorus* compared to *Psittacotherium* include: persistent growth of the canines, molarization of P^3 and P^4, and almost complete coalescence of the roots

of the molars (Patterson, 1949b, pp. 247, 249, 251). Since P^3 and P^4 of *Lampadophorus* are similar to the molars of *Psittacotherium,* it is not possible to be certain whether the loose teeth 40537-26, 40537-33, 40537-61, and 40148-2 are premolars or molars. Too few specimens of *Lampadophorus* have been discovered to determine whether or not the enamel band on the canine ceases growth late in the animal's life. On a cast of a right lower canine from Bear Creek, Montana, AMNH 22182, labeled cf. *Lampadophorus,* the enamel appears to be feathering out.

The Big Bend taeniodont had reached the *Psittacotherium-Lampadophorus* grade, by Patterson's criteria. *Wortmania* from the Puercan is ancestral to *Psittacotherium* (Patterson, 1949b, p. 243). In *Wortmania,* unlike *Psittacotherium* and the Big Bend material, enamel encircles both incisors and canines and the molars have three long, well-separated roots (Patterson, 1949b, pp. 243, 245, 247). The pattern of length of premolar roots in which the root of P^2 is the longest root of the cheek teeth is found in 41364-1, in *Psittacotherium,* and perhaps in *Lampadophorus* (Patterson, 1949b, p. 255). In *Wortmania,* M^1 had the longest roots of the cheek teeth (Patterson, 1949b, p. 248).

At present the evidence suggests that the Big Bend taeniodont is closer to *Psittacotherium* than *Lampadophorus.* Since *Lampadophorus* is poorly known, P^3, P^4, and M^3 being the only upper cheek teeth yet reported for it, this suggestion is tentative. Wilson (1967, pp. 159-162) described the Big Bend material which had been discovered up to that time as *Psittacotherium* cf. *P. multifragum.* There is no evidence that 41364-1 was an extremely old animal in which canine growth, persistent in early life, had finally ceased. The sockets on 41364-1 do not show bone growth indicating that teeth had fallen out before death. Specimen 40536-119 resembles one *Psittacotherium* P^2 (Patterson, 1949b, p. 250), which also has a cuspule-bearing ridge between the protocone and paracone on the posterior side. Patterson (1949b, pp. 255-256) recognized a trend toward caninization of P^1 and P^2 in *Psittacotherium* and its descendants; therefore, the slight molarization of 40536-119 could be considered a primitive character. Specimen 40147-3 is more molarized than any P^2 of *Psittaco-*

therium yet reported, and less molarized than any P^3 of *Lampadophorus* yet reported. It resembles *Psittacotherium* P^3 and P^4 described by Patterson (1949b, p. 251). Some worn *Psittacotherium* molars may have had small hypocones (Patterson, 1949b, p. 249). Since *Lampadophorus* premolars also had small hypocones (Patterson, 1949a, p. 42) the presence of hypocones on the Black Peaks ?molars is not significant. One character of the Big Bend specimens which can be considered advanced over the *Psittacotherium* stage is the presence of prongs of enamel on the labial faces of the cheek teeth. Such prongs are first seen in some *Lampadophorus* molars, and are the first stage in extension of enamel in a band down the labial side of the cheek teeth (Patterson, 1949b, p. 249).

Order CARNIVORA
Family ARCTOCYONIDAE Murray, 1866
Genus *?DEUTEROGONODON* Simpson, 1935
?DEUTEROGONODON sp.
Fig. 19a

Material referred. 40151-1, badly cracked and weathered left mandible fragment with M_2 lacking the labial edge and talonid of M_1.

Description. The M_2 has a small conical paraconid on the anterior face of the metaconid and a complete paracristid. The talonid notch is not deep. The M_2 anteroposterior length is estimated as 10.1 mm.

Discussion. Wilson (1967, p. 161) referred this specimen to *?Claenodon* sp. cf. *C. procyonoides,* and mentioned that the Big Bend specimen was similar in form but larger. The specimen falls into the size range of *"C."* [*Neoclaenodon*] cf. *montanensis,* not *"C."* [*Neoclaenodon*] cf. *procyonoides,* in comparison with Gazin's (1956a, p. 33) *"Claenodon"* specimens from the Bison Basin of Wyoming. Russell (1964, p. 136) places *"C."* *montanensis* in the genus *Neoclaenodon.*

Because of the distinctness of the paraconid of M_2, 40151-1 more closely resembles *Deuterogonodon* than any species of *"Claenodon"* [*Arctocyon*] or *Neoclaenodon.* As far as can be determined, 40151-1 resembles *Deuterogonodon* as described by Simpson (1937a, pp. 190-191, fig. 44). The M_2 of 40151 is approximately 25 percent shorter in anteroposterior length than M_2 of USNM

6161, paratype of *D. montanus*.

Only one species of *Deuterogonodon* has been named, *D. montanus* known from the Torrejonian Gidley Quarry of Montana. Specimen 40151-1 was found 23 meters above the local base of the Black Peaks Formation in the exposure south of the Chisos Mountains, approximately 27 kilometers south of the Black Peaks exposures on Tornillo Flat ·(fig. 1). The similarity of height above the local base of the formation of this locality and more fossiliferous localities on Tornillo Flat is not considered significant for correlation. The poor condition of this specimen makes its identification tenuous. I agree with Wilson (1967, p. 167) in tentatively considering this level of the formation south of the mountains to be Torrejonian in age; however, it still could be either slightly older or younger than localities the same stratigraphic height above the base of the formation on western Tornillo Flat, localities which I consider to be late Torrejonian or early Tiffanian (p. 43).

Genus *TRICENTES* Cope, 1884
Tricentes COPE, 1884, p. 315
TRICENTES TRUNCATUS Cope, 1884
Fig. 19b-h; Table 11
Chriacus truncatus COPE, 1884, p. 313
Epichriacus schlosserianus SCOTT, 1892, p. 296
Tricentes crassicollidens COPE, 1884, p. 315
Tricentes truncatus (Cope), VAN VALEN and SLOAN, 1965, p. 745

Type. AMNH 3101, upper jaw with right P^4-M^3, from middle Paleocene, San Juan Basin, New Mexico.

Material referred. 40537-88, left M_1; ?41365-810, right dP_4; -32, right P_3; -303, right M_1; -616, left M_1; -472, right M_3; -188, left P^4 lacking posterolabial corner; -?822, left M^1 or M^2.

Description. The P^4 has a large sharp paracone and protocone, and a small cusp on the anterolabial corner. It has a posterior cingulum and a labial cingulum. A crest on the posterolabial side of the paracone probably connected the paracone and the missing posterolabial corner. The upper molar has a precingulum that terminates approximately two-thirds of the way toward the lingual edge of the tooth. It has a large hypocone at the lingual end of the postcingulum. The hypocone and protocone are in line anteroposteriorly, and the lingual edge of the tooth is bilobed. The paraconule and metaconule are large. The paraconule is connected to the anterolabial corner by a crest. The ectocingulum is very faint, and there is little ectoflexus. There is no mesostyle.

The dP_4 and M_1 are roughly similar in form, but they differ in proportion. The dP_4 is a much narrower tooth than M_1. The trigonid of dP_4 is anteroposteriorly elongate and is more open, with sharper cusps and a more anteriorly projecting paraconid than the M_1s have. The P_3 has a single large protoconid with a faint crest extending from the tip to a crescentic cingulum at the base of the anterior and posterior sides. M_1 has a large paraconid set slightly lingual to the midpoint. The trigonid is open, and a paracristid is absent. A small precingulid and postcingulid, which originate in the hypoconulid position and slope downward labially, are present. Lingual cingula are weak across the protoconid, but stronger across the median area. The cristid obliqua strikes the posterior trigonid wall even with the protoconid. The talonid basin is deep with a narrow talonid notch partly closed by a cuspid anterior to the entoconid. The hypoconulid is very small and is partly confluent with the entoconid. The paraconid on M_3 is closer to the metaconid and lingual and posterior to the M_1 paraconid position. The notch separating paraconid and protoconid is shallower in M_3, and the lingual cingulum is absent. The cuspid anterior to the entoconid is large, and the hypoconulid is large and projecting.

Discussion. Some confusion exists about the status of the genera *Chriacus* and *Tricentes* and concerning which genus contains the species *T. truncatus*. The genus *Chriacus,* which ranges from the early Torrejonian to the early Wasatchian (Sloan, 1969, fig. 6), should probably be divided into two genera (Simpson, 1936a, p. 8). Van Valen and Sloan (1965, footnote 15) synonymized *Tricentes crassicollidens,* the type species of *Tricentes,* with *Chriacus truncatus,* referred the other species of *Tricentes* to *Mimotricentes,* and synonymized *Metachriacus, Epichriacus,* and possibly *Prothryptacodon* with *Tricentes.* Russell (1967) has followed this usage, but Gazin (1969) has not. I am following the usage of Van Valen and Sloan (1965) in the expecta-

tion that future revision of these genera will confirm this arrangement.

There is little discussion in the literature of material comparable to that from the Big Bend. The most abundant tooth of the Big Bend material is M$_1$. *Tricentes crassicollidens* is known only from its poorly preserved type specimen, a skull with badly damaged upper teeth (Matthew, 1937, pp. 59-60). The only figures of lower molars referred to *"C." [Tricentes] truncatus* are in Gazin (1969) where two incomplete lower molars, M$_3$, and, tentatively, a jaw fragment with P$_3$, P$_4$, and the trigonids of M$_1$ and M$_2$ from the Evanston Formation of Wyoming were referred to cf. *"Chriacus" [Tricentes] truncatus.* The M$_1$ figured by Gazin (1969, pl. 2, fig. 11) has the paraconid slightly more medial than those from the Big Bend. The cristid obliqua strikes the posterior trigonid wall even with the point midway between protoconid and metaconid, lingual to the cristid obliqua-trigonid wall juncture in the Big Bend specimens.

The Big Bend specimens are placed in *T. truncatus* because of resemblances seen in direct comparison with specimens at the University of Kansas, Princeton University, and the American Museum of Natural History. I have considered paraconid shape and position to be particularly important, as did Simpson (1937a, pp. 197, 203) in naming the genera *Metachriacus* and *Mimotricentes.* The Big Bend M$_1$s are very similar in form to M$_1$ of KU 7787, *"Chriacus" [Tricentes] truncatus* of Torrejonian age from the Nacimiento Formation of New Mexico. Specimen 41365-616 is a perfect match in both size and form. P$_4$ is similar in form to that of KU 7787, but was an estimated 20 percent smaller when unbroken. M$_3$ of KU 7787, unlike 41365-472, has no cuspid on the anterior side of the entoconid, and has a labial cingulid. M$_3$ of KU 7787 has a more medial paraconid and a much more posteriorly projecting hypoconulid, which partly accounts for its 35 percent greater length. M$_1$ of AMNH 35419, *Metachriacus (Tricentes* sensu Van Valen*) provocator* from beds of Torrejonian age in Montana, was similar in form to the Big Bend M$_1$s, but approximately 10 percent larger. Comparable Tiffanian *Tricentes,* not yet identified to species, have also been discovered. The Big Bend M$_1$s, P$_3$, P$_4$, and M$_3$ are similar in form and similar in size or less than 12 percent smaller

than specimens in a collection at Princeton University from the Silver Coulee beds of Wyoming, which were identified as *Tricentes* sensu Van Valen. *Tricentes* cf. *"crassicollidens" [truncatus]* was included in a tentative list of the Tiffanian Circle fauna (Russell, 1967).

Referral of the dP$_4$, 41365-810, is tentative and referral of the single upper molar, 41365-822, is even less certain. Each may represent another genus, but the resemblance between the dP$_4$ and the M$_1$s makes referral to this species reasonable until more evidence is found. The chief difference between 41365-822 and M^1 of AMNH 3101 (Matthew, 1897, fig. 7), type of *"C." [Tricentes] truncatus,* and M^1 of KU 7787, is the greater lingual extent of the hypocone and the continuation of the cingulum across the lingual face of the protocone on AMNH 3101 and KU 7787. The M^2 of AMNH 3101 has a strong anterolingual projection of the cingulum and KU 7787 M^2 has a small cusp on the cingulum at the anterolingual corner of the tooth. In 41365-822 the protocone base forms a similar squared anterolingual corner, but the cingulum does not cross the anterolingual area.

Genus *ARCTOCYON* DeBlainville, 1841

Russell (1964, pp. 134-137) provides a synonymy of this genus. He has synonymized the genus *Claenodon* with *Arctocyon,* and I have followed his usage.

ARCTOCYON cf. *A. FEROX* (Cope), 1883
Fig. 20a-b; Tables 12, 13
Mioclaenus ferox COPE, 1883, p. 547
Claenodon ferox (Cope), SCOTT, 1892, p. 289
Arctocyon ferox (Cope), RUSSELL, 1964, p. 137

Type. AMNH 3268, teeth and parts of skeleton, from middle Paleocene, San Juan Basin, New Mexico.

Material referred. 41366-81, worn left M^2; -65, left M^3.

Description. The M^2 is too badly worn to show details. It has a strong, crenulated labial cingulum. A crenulated cingulum encircles M^3. M^3 has no hypocone.

Discussion. Arctocyon ferox is the largest North American *Arctocyon* with which the Big Bend material can be compared. *"Claeno-*

don" [Arctocyon] acrogenius, reported only from the Tiffanian of the Bison Basin of Wyoming, was described as comparable in size to the largest "C." [Arctocyon] ferox (Gazin, 1956a, p. 34). No M^2 or M^3 of "C." [Arctocyon] acrogenius have been reported.

The M_2 of A. ferox of North America and A. primaevus, the largest European species of Arctocyon, are similar in size (Russell, 1964, fig. 21). Size comparison of the Big Bend specimens with published data on A. ferox and A. primaevus upper molars shows that the Big Bend specimens are larger (table 12) and outside the range of A. primaevus. No range for A. ferox upper molars has been published. Comparison with USNM 20797, Tiffanian "Claenodon" [Arctocyon] cf. "C." ferox from the Bison Basin (Gazin, 1956a, p. 33) yields V's of less than 10 (table 13).

The geologically oldest A. ferox (also the first described) were from the Torrejonian of the San Juan Basin. Tiffanian A. ferox have also been reported from the Bison Basin, Wyoming, the Crazy Mountain field of Montana, and the Fossil Basin of Wyoming according to Russell (1967). Comparison of the Big Bend material with Simpson's (1937a, fig. 36) drawings of "C." [Arctocyon] ferox from the Melville Formation of Montana (Fort Union No. 3) show little difference in form. The importance of the difference in size discussed above cannot be evaluated until more specimens are available.

Undescribed genus and species*
Fig. 20c-k; Table 14

Material referred. 41365-168, right P^3; -137, right P^3; -389, left P^4; -764, left M^1; -801, right M^2; -848, left M^2; -38, left M^3; -567, left P_2; -39, left P_2 with broken heel; -633, left P_3; -346, mandible fragment with right P_3-P_4; -342, left P_4; -531, right M_1; -580, left M_1; -805, left M_2; -80, right M_3; 41366-30, canine, probably left lower with tip broken off; 41376-2, left mandible fragment with M_2-M_3 and roots of M_1.

Description. The canine is vertically striated. Cusps of both upper and lower premolars and some of the molars are also similarly, but less densely, striated. Striations are knobby and irregular, branching and anastomosing.

The P^3 is triangular with a single large median cusp surrounded by a cingulum. The lingual point bears a small cusp on the cingulum. Crests connect the median cusp and the anterolabial and posterolabial corners. P^4 has a large protocone with a preprotocrista. M^1 has both a preprotocrista and a postprotocrista and a distinct hypocone. The postprotocrista ends at the metacone. The posterior cingulum reaches the posterolabial corner. The weak ectocingulum bears a small mesostyle. The cingulum on the anterolabial corner is very strong. M^2 is wider than M^1. The hypocone is large and the lingual portion of the tooth is bilobed. Both the preprotocrista and the postprotocrista connect to a strong ectocingulum. Specimen 41365-801 has a metaconule, and 41365-848 does not. Specimen 41365-848 has a mesostyle, and 41365-801 does not. The anterolabial corner of M^2 extends much farther labially than the posterolabial corner, and the anterolabial corner of M^2 does not extend proportionally as far anteriorly as it does in M^1. M^3 is similar to M^2 except that the anterior edge of M^3 is strongly convex and the cingula cross the lingual side of the protocone.

The P_2 has a large protoconid and a small heel. A faint cingulum runs along the anterior tooth edge, and a strong one bounds the heel. Sharp crests run down the anterior and posterior sides of the protoconid, and a thicker, less distinct ridge runs down the lingual side. On P_3 and P_4 the crests are less simple and less distinct. The posterior crest splits into two ridges near the heel on P_3. On P_4 one branch of the posterior crest forms a weakly developed metaconid, and one branch runs straight backward to join the posterior cingulum. The latter is probably analogous to the cristid obliqua. The P_4 of 41365-346 has a small cusp on the posterolingual side of the heel. Lower molars have strong precingulids and large, high, median paraconids. Paracristids connect the paraconids and protoconids. The molar trigonids are open. There is no consistent difference in form between M_1 and M_2; on both, the strong cristid obliqua strikes the posterior trigonid wall at approximately its midpoint, talonid basins are smooth and shallow, and talonid notches are deep and broad. A strong hypoconulid is present. Postcingulids are present, although very weak on some specimens. The paraconids are smaller and the

trigonids more open on M_3 than on the other lower molars. The M_3 of 41376-2 has two cusps in the paraconid position; 41365-80 has one. The M_3 talonid has a large hypoconulid and a strong postcingulid on the posterolabial side. Specimen 41365-80 has a large cusp between the hypoconulid and the hypoconid, and 41376-2 has a large cusp between the hypoconulid and the entoconid, but the talonid shape of the two teeth is still quite similar.

Discussion. These specimens belong to the same genus as an undescribed animal represented in several collections, probably Tiffanian, from Wyoming which are being studied by Mr. D. Parris. This animal is currently believed to represent an unnamed genus and species of arctocyonid. Important features in which its teeth are similar to the Big Bend teeth include trigonid shape, hypocone shape and position, form of the anterolabial corners of upper molars, and vertical striations.

Without more comparative material it is impossible to be sure if 41366-30 is an upper or lower canine. The similarity of form of M_1 and M_2 also makes assigning specimens to one or another difficult. The loose M_1s and M_2s listed above were identified on size differences. The convexity of the anterior edge of M^3 is not seen in the M^3 of the Wyoming animals. The Big Bend M^3 may not belong to the arctocyonid under discussion. If it does not, then the teeth described above as M^2 might be M^3, although they more closely resemble M^2 of the Wyoming animal in form.

I believe that the Black Peaks animal described above and the specimens from Wyoming belong to the same species, but this question cannot be settled until Mr. Parris has completed his study. There are several minor differences between the Black Peaks specimens and those Wyoming specimens which I have examined at Princeton University. The Black Peaks lower molars are narrower. In the Wyoming M^2 the cingula cross the lingual side of the protocone, but in the Big Bend animal the cingulum is faint on the lingual side of the M^2 protocone, and M^2 is shorter anteroposteriorly.

Order CONDYLARTHRA
Family HYOPSODONTIDAE Lydekker, 1889
Genus *PROMIOCLAENUS* Trouessart, 1904
Promioclaenus TROUESSART, 1904, p. 43

PROMIOCLAENUS ACOLYTUS (Cope)
1882
Fig. 21a; Table 15
Hyopsodus acolytus COPE, 1882
Mioclaenus minimus COPE, 1882
Mioclaenus acolytus (Cope), OSBORN, 1902, p. 170
Ellipsodon acolytus (Cope), MATTHEW, 1937, p. 200
Promioclaenus acolytus (Cope), WILSON, 1956, p. 115

Type. AMNH 3208, upper and lower jaws, left P^3-M^2_3, from Paleocene (probably middle Paleocene), San Juan Basin, New Mexico.

Material referred. 41274-10, left mandible fragment with moderately worn M_2-M_3.

Description. On M_2 there is a faint precingulid and a labial cingulid which does not cross the labial side of the hypoconid. A paracristid connects the protoconid to the small paraconid which is almost completely confluent with the metaconid at this stage of wear. The metaconid is bulbous and larger than the protoconid. The trigonid is wider than the talonid. The talonid notch is deep but narrow. The hypoconulid is large. The posterolingual part of the posterior talonid wall is high, but there is no distinct entoconid. M_3 differs from M_2 in having a slightly more distinct paraconid, a distinct but crescentic entoconid, and a narrower talonid. The hypoconulid projected, but breakage makes the degree uncertain.

Discussion. Wilson (1956) revised the genera *Ellipsodon* and *Promioclaenus,* placing four species, *P. shephardi, P. aquilonius, P. acolytus,* and *P. lemuroides,* which had previously been referred to *Ellipsodon* in *Promioclaenus.* The Big Bend specimen is placed in *Promioclaenus* instead of *Ellipsodon* mainly because its M_3 is not extremely reduced. Wilson (1956, p. 112) described *Ellipsodon* as having M_3 extremely reduced and molar paraconids ". . . usually nearly if not entirely indistinguishable." Wear on 41274-10 makes the original degree of distinctness hard to judge, but the paraconids are still distinguishable (fig. 21a).

Simpson (1937a, p. 233) described the four species "*E.*" [*Promioclaenus*] *aquilonius,* "*E.*" [*Promioclaenus*] *acolytus,* "*E.*"[*Promioclaenus*] *lemuroides,* and *E. inadequidens* as forming a series in which each species is fairly close

to its neighbors, but end members differ considerably from each other. Wilson (1956, p. 113) considered *P. shephardi, P. aquilonius,* and *P. acolytus* to be closely related to one another with *P. lemuroides* somewhat more distantly related. *"E." [Promioclaenus] shephardi* from the Puercan Dragon fauna is characterized by having more distinct paraconids than the other species which are now referred to *Promioclaenus* (Gazin, 1939, p. 283). The Big Bend specimen falls midway in the series of *Promioclaenus* species, and thus is assigned to a species on minor differences in paraconid development and M_3 size and shape. The paraconid form of 41274-10 is more similar to *Ellipsodon* than to *P. shephardi,* because 41274-10 has reduced paraconids. *P. lemuroides* lacks distinct paraconids and is larger than 41274-10 (Matthew, 1937, p. 202). Specimen 41274-10 falls within the size range of *P. aquilonius* (Simpson, 1937a, p. 234). The hypoconulid of M_3 of 41274-10 is damaged, but it could not have been as sharply projecting as that figured for the type specimen of *"E." [Promioclaenus] aquilonius* (Simpson, 1937a, fig. 62). The average M_3 of *"E." [Promioclaenus] aquilonius* from Gidley Quarry is six percent longer than the average M_2 (Simpson, 1937a, table 51). Even before the breakage M_3 of 41274-10 must have been shorter than M_2. *"E." [Promioclaenus] acolytus* is similar in size to *"E." [Promioclaenus] aquilonius* (Simpson, 1937a, p. 234), and thus to the Big Bend specimen. The *P. acolytus* M_3 is similar in form, although slightly longer, to M_3 of 41274-10 (Matthew, 1937, fig. 51).

P. pipiringosi from the Bison Basin of Wyoming, the only *Promioclaenus* species yet reported from the Tiffanian, has lower molars larger and narrower transversely than those of 41274-10. *P. pipiringosi,* described as similar in size to *P. lemuroides* (Gazin, 1956a, pp. 36-37), has an M_2 13 percent longer than M_2 of 41274-10. The Bison Basin M_2 is too worn for comparison of paraconid form with 41274-10 (Gazin, 1956a, pl. II, fig. 1), and no M_3 of *P. pipiringosi* has yet been described. *P. acolytus, P. aquilonius,* and *P. lemuroides* have only been reported from beds of Torrejonian age (Russell, 1967). *P. acolytus* is known only from the San Juan Basin. Specimen 41274-10 was found lower in the Black Peaks Formation than the bulk of the fauna, and is therefore somewhat older (p. 43).

Genus *HAPLALETES* Simpson, 1935
Haplaletes SIMPSON, 1935, p. 243
HAPLALETES DISCEPTATRIX Simpson,
1935
Fig. 21b-g; Table 16
Haplaletes disceptatrix SIMPSON, 1935, p. 244

Type. USNM 9500, right mandible with P_3-M_3, from Gidley Quarry, middle Paleocene, Montana.

Material referred. 41365-351, right M^1 with ectocingulum broken off; -8, labial half of right M^1; -358, right M^2 lacking the anterolabial corner; -849, partially digested or water worn right M^3; -457, right P_4; -361, right M_1; -193, left M_2.

Description. Upper molars have both a pre- and postcingulum. The latter terminates at a small hypocone. The lingual side of the tooth is bilobed, and the tooth is slightly skewed anteriorly. The paraconule and metaconule are distinct, but conule cristae are very faint or absent. The ectocingulum and the ectoflexus are weak, and mesostyles are absent. Parastyle and metastyle crests are strong. M^2 differs from M^1 in having a longer lingual slope of the protocone and a stronger hypocone and being transversely wider and slightly more anteriorly skewed. The features of M^3 are blurred, but it lacks a hypocone and has the metacone reduced.

P_4 has a distinct conical paraconid and metaconid. The metaconid is low on the posterolingual side of the protoconid, with its tip only slightly higher than the paraconid and the posterior talonid rim. The metaconid is located at the anteroposterior midpoint of the tooth. The maximum width of the tooth is across the talonid. A crest runs from the paraconid to the tip of the protoconid and then to the single large crescentic cusp at the midpoint of the posterior talonid wall, producing a small posterolingually directed branch at the level of the metaconid. There is a tiny cuspule on the posterolingual tooth corner. M_1 has a precingulid. Its paraconid is small, slightly lingual to the median point, and set low on the trigonid. The paracristid forms a squared anterolabial corner and a very shallow, almost closed, trigonid basin. Protoconid and metaconid are large and conical. The talonid is deeply basined with a wide, shallow talonid notch. The hypoconulid is large, conical, and

posteriorly projecting. On M_2 it is median, and on M_1 it is closer to the entoconid. M_2 lacks a paraconid. Its paracristid completely encloses the small shallow trigonid basin.

Discussion. Simpson's (1937a, pp. 226-227) revision of the Paleocene Hyopsodontidae'emphasized the form of P_4 and of the molar paraconids and the lack of mesostyles in distinguishing the genus *Haplaletes,* and these criteria place the Big Bend specimens in *Haplaletes.* They differ from the genus Simpson (1937a, p. 227) considered most closely similar, *Litolestes* (placed in Insectivora by Van Valen, 1967), in having less transverse and angulate upper molars, and a more distinct metaconid and talonid on P_4.

Direct comparison with Simpson's type, USNM 9500, and paratype, USNM 9555, of *H. disceptatrix* reveals few differences. P_4, 41365-457, resembles P_4 of USNM 9500 much more closely than comparison with Simpson's (1937a, p. 244) figures would indicate. P_4 of USNM 9500 has the metacone slightly higher on the tooth and the cusp on the lingual heel corner stronger than in 41365-457. Specimen 41365-361 is almost an exact duplicate in size and form for M_1 of USNM 9500. Specimen 41365-193 is smaller than M_2 of USNM 9500 and lacks a strong labial cingulum. Upper molars of USNM 9555 have stronger ectocingula than the Big Bend upper molars. The hypocone of M_1 of USNM 9555 is larger than that of 41365-351, but in the same position, and the hypocone of M_2 of USNM 9555 is set slightly less lingual than the hypocone of 41365-358.

H. disceptatrix, known from the Torrejonian Gidley Quarry, Montana, is the type species and the oldest of the four species of *Haplaletes.* The other three species, *H. diminutivus,* originally described from the Dell Creek fauna of Wyoming, and *H. pelicatus* and *H. serior,* originally described from the Bison Basin of Wyoming, are Tiffanian. These species are mainly distinguished on size. The Big Bend P_4 is the same length as P_4 of the type of *H. disceptatrix,* and M_2 falls within the range of lengths for M_2 of *H. disceptatrix* given by Simpson (1937a, table 55; this paper, table 16). The Big Bend lower molars are a little narrower but there is only a 10 percent difference from the narrowest teeth measured by Simpson (1937a, table 55). No lower teeth have been referred to *H. diminutivus* (Dorr,

1952, p. 87). The transverse width of M_1 of UMMP 27231, type of *H. diminutivus,* is 23 percent less than the width of M_1 of USNM 9555, *H. disceptatrix,* and the transverse width of M_2 of UMMP 27231 is also 23 percent less than that of M_2 of USNM 9555 (Dorr, 1952, p. 87; Simpson, 1937a, table 56). The lingual sides of upper molars of *H. diminutivus* are less bilobed than those of *H. disceptatrix* described by Simpson (1937a, p. 244) and the Big Bend specimens. Gazin (1956a, pp. 39-40) described *H. pelicatus* as having lower molars 20 percent longer than those of *H. disceptatrix,* and *H. serior* as having lower molars 15 percent longer than those of *H. pelicatus.* Gazin (1956a, p. 39) described the premolars of *H. pelicatus* as being more inflated than those of *H. disceptatrix.* P_4 of the *H. pelicatus* type is narrower in proportion to its length than P_4 of *H. disceptatrix* (Gazin, 1956a, p. 40; Simpson, 1937a, table 55). P_4 of *H. pelicatus* has a proportionally wider protoconid than P_4 of *H. disceptatrix* or the Big Bend specimen (Gazin, 1956a, pl. 9, fig. 1; Simpson, 1937a, fig. 68). The lower molars of *H. serior* are proportionally wider than those of *H. disceptatrix* (Gazin, 1956a, p. 40). The Big Bend specimens agree more closely in both size and form with *H. disceptatrix* than with the other species of *Haplaletes.*

Genus *PROTOSELENE* Matthew, 1897
Protoselene MATTHEW, 1897, p. 317
PROTOSELENE OPISTHACUS (Cope), 1882
Fig. 21h; Table 17
Mioclaenus opisthacus COPE, 1882, p. 833
Hemithlaeus [=Mioclaenus] baldwini COPE, 1882, p. 833
Protoselene opisthacus (Cope), MATTHEW, 1897, p. 317

Type. AMNH 3275, left P_4-M_3, right M_1-M_3, from middle Paleocene, San Juan Basin, New Mexico.

Material referred. 40537-129, left M_1-M_3 in mandible fragment.

Description. The M_1 of 40537-129 is worn, and its anterior edge and protoconid are broken. Both M_2 and M_3 have a precingulid. On M_2 the paracristid reaches the anterolabial side of the metaconid. The paraconid on M_2-M_3 is not clearly separated from the paracristid, and is partly confluent with the protoconid. The paraconid of M_2 is small and in-

distinct. The paraconid of M_3 is larger, more median, and less confluent with the protoconid than the paraconid of M_2, and the trigonid of M_3 is open. A small cusp is present on the anterior side of the M_2 entoconid and on the anterolingual side of the M_3 entoconid. The hypoconulid on M_2 is single, and it connects with the labial half of the postcingulid. The hypoconulid of M_3 is double, with the labial conulid only slightly larger than the lingual conulid.

Discussion. In Simpson's (1937a, pp. 226-231) discussion of the Paleocene genera of Hyopsodontidae, the genus *Protoselene* was described as divergent, more sharply defined than the other genera. Simpson (1937a) gave the most recent comparison of *Protoselene* and the other genera of the Hyopsodontidae. He described *Protoselene* as having paraconids median to subinternal, entoconids distinct, M_3 large, and teeth more lophodont than the other Paleocene members of the Hyopsodontidae (Simpson, 1937a, p. 227). Only two species of the genus *Protoselene* have been named, *P. opisthacus* from the San Juan Basin, Torrejonian of New Mexico, and *P. novissimus* from the Bison Basin, Tiffanian of Wyoming, and *P. novissimus* was referred to this genus with some doubt (Gazin, 1956a, pp. 40-41). The only other available material of *P. novissimus,* aside from the type, USNM 20572, a mandible fragment with M_2-M_3, is an isolated M_1, USNM 21023.

The most striking differences in form observed were in the hypoconulid region of M_3 when 40537-129 was compared directly with *P. novissimus* at the U. S. National Museum and with the collection of *P. opisthacus* from New Mexico at the American Museum of Natural History. The M_3 of the *P. novissimus* type and of the *P. opisthacus* type have a single hypoconulid. Both specimens with double hypoconulids and specimens with single hypoconulids were found in the American Museum of Natural History collection from the *Pantolambda* zone, Nacimiento Formation, San Juan Basin. Two specimens of *P. opisthacus,* AMNH 3282 and AMNH 2435, both labeled as from the *Pantolambda* zone, have double hypoconulids in which the two conules are approximately equal as in 40537-129. Other *P. opisthacus* from the American Museum of Natural History collection show what may be intermediate stages between the double hypo-

conulid and single hypoconulid condition. The specimens AMNH 3273a and AMNH 3277 have a small conulid labial to the hypoconulid, AMNH 15973 has a small conulid on the lingual side of the hypoconulid, and AMNH 16614, only identified on its label as *Protoselene,* has two small conulids, one low on the posterolingual side of the hypoconulid, and one low on the posterolabial side. *Dracoclaenus,* described only from the Dragon fauna of Utah, may be ancestral to *Protoselene* (Sloan, 1969, p. 443). One M_3 has been described as possibly belonging to *Dracoclaenus;* it has one hypoconulid and three small cusps in the entoconid position (Gazin, 1939, p. 283). Gazin (1939, p. 283) described M_1 and M_2 of *Dracoclaenus* as having a small cusp on the anterior crest of the entoconid. The anteriormost of the three small cusps on the *Dracoclaenus* M_3 may be homologous to the cusp on the anterior of the entoconid on M_1 and M_2, and the posterior of the three small cusps may be homologous to the small conulid lingual to the hypoconulid in AMNH 15973, *P. opisthacus.* The evolutionary significance of the double hypoconulid is not clear enough for it to be given much weight in separating 40537-129 from *P. novissimus,* or associating 40537-129 with *P. opisthacus.* The t-test for the comparison of a single specimen with a sample (Simpson *et al.,* 1960, p. 183) was used to compare USNM 20572 and 40537-129 with the specimens of *P. opisthacus* from New Mexico measured in the American Museum of Natural History (table 17). These specimens of *P. opisthacus* are not from the same locality, nor are they of the same age, but V for length and width of M_2 and M_3 is under ten, which indicates that the variability is not greater than that which could be expected for a single mathematical population (Simpson *et al.,* 1960, p. 207). The difference in length of M_2 between USNM 20572, type of *P. novissimus,* and *P. opisthacus* is not significant. The difference in length of M_2 of 40537-129 and *P. opisthacus* is significant. The M_3 of USNM 20572 and M_3 of 40537-129 are equal in length, and both fall within the range of lengths for *P. opisthacus* M_3. The differences in width of M_2 and M_3 of 40537-129 and USNM 20572 compared to *P. opisthacus* are not significant.

Gazin (1956a, pp. 40-41) described *P. novissimus* as having molars smaller and more

slender, crests lower, and the paraconid of M_2 and M_3 more isolated from the protoconid and the metaconid than *P. opisthacus.* The M_2 and M_3 of the type *P. novissimus,* USNM 20572, are narrower than M_2 and M_3 of 40537-129. The paraconids of M_2-M_3 of USNM 20572 are sub-internal and are isolated from the protoconid, unlike the paraconids of M_2-M_3 of 40537-129 (Gazin, 1956a, pl. 8, fig. 1). The paraconids of M_2-M_3 of 40537-129 are slightly labial to the median point. USNM 20572 is worn; therefore, I cannot determine if there is a significant difference in crest height between it and 40537-129.

I believe that the differences between 40537-129 and USNM 20572 in paraconid and paracristid arrangement rule out placing 40537-129 in *P. novissimus,* despite the fact that USNM 20572, from the Saddle locality of the Bison Basin, Wyoming, is probably nearer in age to 40537-129 than any *P. opisthacus* specimen yet reported. No specimens of *P. opisthacus* younger than those found in the *Pantolambda* zone in the San Juan Basin of New Mexico have previously been reported.

Family PHENACODONTIDAE Cope, 1881

The phenacodontid condylarths are badly in need of revision. The previously-used criteria for separating the genera *Gidleyina, Ectocion, Tetraclaenodon,* and *Phenacodus* are ambiguous, with so many exceptions to the rules that there are no rules left. West (1971, pp. 4-5) is preparing a review of the family in which a statistical treatment will be used.

The nature of the Big Bend phenacodontid sample adds to the difficulty in determining the genera and species present. Phenacodontid condylarths are the most numerous fossils found in float on western Tornillo Flat; however, samples, particularly of the smallest phenacodontids, are still small. The most numerous tooth is M_3, of which there are only ten in the collection. Premolar form is important at both the generic and specific level in phenacodontids, but only one specimen having lower premolars is available, and no premolars of the smallest phenacodontids, referred to *Ectocion,* are available. No specimens of *Phenacodus grangeri* or *Ectocion* have been found on eastern Tornillo Flat, but specimens referable to all three species described below occur at Joe's Bonebed.

Genus *PHENACODUS* Cope, 1873
Phenacodus COPE, 1873, p. 3

Tetraclaenodon is ancestral to the other phenacodontids (Radinsky, 1966), so the division of the genera *Tetraclaenodon* and *Phenacodus* must sometimes be arbitrary. *Tetraclaenodon* had been reported to range into the earliest Tiffanian in Montana, but otherwise it is restricted to the Torrejonian (West, 1970, p. 855). The largest Big Bend phenacodontid, *Phenacodus grangeri,* is more advanced than *Tetraclaenodon.* The M^3 has a prominent hypocone. There is no paraconid on lower molars. P^4 has a strong metacone. The dP^3 has a metacone, unlike dP^3 of *Tetraclaenodon* (West, 1971, pp. 8-9). Upper molars have strong mesostyles; however, some *T. puercensis* have mesostyles (Gazin, 1956a, p. 45). No M^3s of Big Bend *P. matthewi* are available. Differences in shape between the available *P. matthewi* teeth and the larger Big Bend *P. grangeri* specimens are minor.

Although there are no consistent differences in form among the specimens referred to *Phenacodus,* the coefficient of variation for the whole sample is more than 10 for several measurements. Simpson (1937b, p. 18) calculated Vs ranging from 3.6 to 6.4 for length and width of M_1, M_2, and M_3 of 25 *P. primaevus* from the Clark Fork localities of the Bighorn Basin of Wyoming.

Wilson (1967) referred 40147-19 to *?Tetraclaenodon puercensis* and 40148-4 and 40148-6 to *Phenacodus* or *Gidleyina* sp. Newly discovered Big Bend specimens have partially bridged the gap between these specimens and all are placed in *P. matthewi* (fig. 24, table 20). There is no completely satisfactory way to classify the Big Bend *Phenacodus* specimens at the species level (fig. 24, table 19). Specimens 41366-60 and 41366-69 are intermediate in size between the largest *P. grangeri* specimens and the small specimens referred to *P. matthewi;* their referral to *P. grangeri* is arbitrary.

PHENACODUS GRANGERI Simpson, 1935
Figs. 22a-c; 23a-b; Table 18
Phenacodus grangeri SIMPSON, 1935, p. 23

Type. AMNH 17185, right maxilla with M^1-M^2 and outer half of M^3, from the Tiffanian of Colorado.

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Material referred. 41274-2, left M_1 or M_2; 40148-13, right P^4; -23, right dP^3, right P^4, right M^2; -10, left M^2; 40642-1, left M_3; 41368-1, left P^4, left M^2; 41273-1, left mandible fragment with worn M_1-M_2 and roots of P_4 and M_3; 41366-49, cracked left P^3; -72, left P^4; -60, left maxilla fragment with posterior half of P^4 and M^1-M^2; -11, left P^3, right P^4, and right maxilla fragment with M^2-M^3; -36, left maxilla fragment with M^2-M^3 and crushed M^1; -69, left maxilla fragment with M^2 and crushed M^1; -12, left M^2 with hypocone broken off and left maxilla fragment with M^3; -29, right mandible fragment with P_3-M_1; -37, right mandible fragment with M_1-M_3; -35, left mandible fragment with M_2-M_3 and crushed M_1; -63, left mandible fragment with M_2 and crushed M_1 and M_3; -61, right mandible fragment with M_2-M_3 and roots of P_4 and M_1; -40, right mandible fragment with M_3; -67, right M_3; -39, left mandible fragment with M_3 with broken anterolabial edge; -38, right M_3.

Description. All of the upper teeth are low-crowned and blunt-cusped, with faintly wrinkled enamel. The dP^3 has a large conical protocone at the posterolingual corner. The tooth is triangular with a median paracone. Wear and breakage of the tooth make the degree of confluence of metacone and paracone hard to judge, but a distinct metacone is present. There is a strong crescentic parastyle. The P^3 has a large protocone and a paracone with a smaller metacone partly confluent with it. Cingula are strong on the anterior and posterior sides of the triangular tooth, but weak on its labial side. There is a crescentic parastyle. The paracone and metacone are less confluent on P^4 than on P^3. A small hypocone is present on all the P^4s except 41368-1. P^4 has a paraconule; 41368-1, but not the other P^4s, has a metaconule. Upper molars have strong mesostyles which connect the ectocingulum to the paracone and metacone. Paraconules and metaconules are distinct on upper molars, but the paraconules are stronger. M^3s have strong hypocones.

The enamel on the lower teeth is faintly rugose and the cusps of lower molars are bulbous. P_3 of 41366-29 has a small but distinct paraconid. There is a small cuspule on the protoconid anterior and posterior to the major cusp and a small metaconid on the posterolingual side of the protoconid. The cristid obliqua swings posterolingually to define a small basin. On P_4 of 41366-29, the paraconid is large, but still set low, and the metaconid is as large as the protoconid. Both the protoconid and metaconid bear a small accessory cuspule anterior and posterior to the main cusp. There is a small hypoconid and small cuspules on the posterior talonid rim, but no entoconid. Lower molars have high, closed trigonids. Metaconids have a small accessory cuspule anterior and posterior to the main cusp; there are no distinct paraconids. The molar protoconids lack accessory cuspules. Entoconids are distinct on M_1, M_2, and some M_3s. On other M_3s several smaller cuspules occur in the entoconid position. Unworn lower molars show a small cuspule on the anterior side of the entoconid. Lower molars have distinct hypoconulids equidistant from hypoconid and entoconid. The posterior edge of the heel on some of the M_3s is gently rounded; on others the hypoconulid forms a projecting spur.

Discussion. Simpson (1935b, p. 24), in his original description of *P. grangeri* from the Tiffany fauna, stated that there is no difference in size between *P. grangeri* and the smallest *P. primaevus* subspecies, and he gave only a few differences in form, all of which apply to the Big Bend *P. grangeri*. The M^2 of the type of *P. grangeri* falls well within the size range of Big Bend *P. grangeri* and is similar in width-to-length proportion (fig. 24). The P_4 of *P. grangeri* is described by Simpson (1935b, p. 24) as having a low, indistinct entoconid; P_4 of 41366-29 lacks an entoconid altogether.

P. grangeri is, I think, ancestral to *P. primaevus*. Specimen 40143-1, *Phenacodus* cf. *P. primaevus* from the overlying Hannold Hill Formation (Wilson, 1967, p. 165), a mandible fragment with M_1 to M_3, is similar in size and form to the Big Bend *P. grangeri* lowers. West (1971, pp. 14, 17-18) retains both *P. grangeri* and *P. primaevus,* and gives the range of *P. grangeri* as Tiffanian of Colorado and Wyoming and of *P. primaevus* as late Tiffanian to Bridgerian of Texas, New Mexico, Colorado, and Wyoming. The earliest reported occurrence of *P. primaevus* is at the Clark Fork locality in the Bighorn Basin of Wyoming (Russell, 1967).

PHENACODUS cf. *P. MATTHEWI*
Simpson, 1935

Figs. 22d-e; 23c; Table 20
Phenacodus matthewi SIMPSON, 1935, p. 24

Type. AMNH 17191, right mandible with M_2-M_3, from Tiffanian of Colorado.

Material referred. 41274-3, right M_1 or M_2 with anterior edge and protocone broken off; 40147-19, left P^4, M^1; 40148-4, left M^2; -6, right M_1-M_3; 41365-569, left M_1 or M_2; 41366-27, left M^1-M^2.

Description. Although they are smaller, the teeth assigned to *P. matthewi* are similar in form to those assigned to *P. grangeri.*

Discussion. Simpson (1935b, pp. 23-25) described three species of *Phenacodus* from the Tiffany fauna, *P. grangeri, P. matthewi,* and *P. gidleyi. P. matthewi* is intermediate in size between *P. gidleyi* and *P. grangeri,* and 40148-6 is intermediate in size between *P. matthewi* and *P. grangeri,* but closer to the former (table 19). No upper teeth of *P. matthewi* have been reported, but Big Bend M_2 and M_3 resemble quite closely the single specimen of *P. matthewi* described by Simpson (1935b, pp. 24-25). They have a strong cuspule on the anterior side of the entoconid, as does the type, but they lack the distinct paraconid seen in M_2 of the type.

Genus ECTOCION Cope, 1882
Ectocion COPE, 1882, p. 522
Gidleyina SIMPSON, 1935, p. 240

West (1971, p. 5) considers *Gidleyina* to be synonymous with *Ectocion,* and I have followed his usage. The specimens referred to *Ectocion* cf. *E. montanensis* are smaller than the Big Bend *P. grangeri* and *P. matthewi* (fig. 24), but they are not a continuation of that series. They show differences in form from the Big Bend *P. grangeri* and *P. matthewi.* For example, 41365-16, the single unworn lower molar, has sharper cusps and a more strongly twinned entoconid than Big Bend *Phenacodus* lowers. The trigonid of 41365-16 is proportionally longer. The grouping of the specimens referred to *Ectocion* is tentative, partly because so few specimens are available and partly because the most closely comparable species are rather poorly known.

ECTOCION cf. *E. MONTANENSIS* (Gidley), 1935
Figs. 22f-h; 23d-e; Table 21

Gidleyina montanensis (Gidley), SIMPSON, 1935, p. 240
Ectocion montanensis (Gidley), WEST, 1971, p. 22

Type. PU 12048, left maxilla fragment with P^3-M^2 and probably associated right P^2, from 305 meters above Gidley Quarry, Montana.

Material referred. 40536-167, right maxilla fragment with M^2; 41365-825, left M^1; -784, partially digested right M^1; -16, left M_1 or M_2; -307, worn right M_3.

Description. The three upper molars have strong mesostyles, metaconules, and paraconules. Crests connecting the conules to the protocone are very weak in 41365-825, but distinct in 41365-784 and 40536-167. Specimen 40536-167 is much wider than the other two teeth because of its labially-extending anterolabial corner. Its mesostyle is more prominent than the mesostyle of the other two.

Specimens 41365-16 and 41365-307 have closed basined trigonids with no distinct paraconids. Specimen 41365-307 is too worn to reveal much detail, but on 41365-16 the metaconid bears a small cuspule on its anterior and posterior side. The enamel is wrinkled and the trigonid basin and the paracristid bear many small cuspules. Specimen 41365-16 has a distinct, sharp hypoconid, hypoconulid, and entoconid, and a cuspule on the anterior side of the entoconid. The cristid obliqua is high and sharp.

Discussion. Three species which are now placed in *Ectocion* were named in Simpson (1935c, pp. 239-241), *"G." montanensis, "?G." silberlingi,* and *"?Tetraclaenodon" superior,* all from the upper Paleocene of Montana. Later workers have suggested that these species might be synonymous and should all be called *"G." [Ectocion] montanensis* (Gazin, 1956a, pp. 43, 44; Dorr, 1958, p. 1224), but did not formally synonymize them. Gazin (1956a, p. 43) described *"G." [Ectocion] wyomingensis* from the Tiffanian of Wyoming as having low, weak paraconids on the lower molars, trigonids less prominently basined than in *"G." [Ectocion] superior,* and distinctive strong protocone crests. In direct comparison of 40536-167 and M^2 of USNM 20795, *"G." [Ectocion] wyomingensis,* the crests between protocone and conules are stronger in USNM 20795, and USNM 20795 has a strong crest connecting the paracone

and the anterolabial corner. This crest is weak on 40536-167. Simpson (1937a, fig. 72) illustrated PU 12048, "G." [Ectocion] montanensis, as having the crest connecting the paracone and the anterolabial corner on M^2 similar to that of 40536-167. "G." [Ectocion] silberlingi and "G." [Ectocion] superior were described as having the lower molar paraconids vestigial or absent and the trigonids closed and basined (Simpson, 1937a, pp. 253, 254). No lower molars of "G." [Ectocion] montanensis were available when Simpson named it. The closed, basined trigonids of the Big Bend Ectocion lower molars suggest a closer affinity with the E. montanensis-silberlingi-superior group than with E. wyomingensis. In direct comparison, 41365-16 is similar in form and size to M_2 of USNM 11913, the type of "?G." [Ectocion] superior. The most striking difference between them is that the conule anterior to the entoconid on M_2 of USNM 11913 is weaker than in 41365-16.

West (1971, p. 22) gave the range of E. montanensis as Tiffanian of Montana and the range of E. wyomingensis as Tiffanian of Colorado and Wyoming. Reference of the Big Bend Ectocion specimens to a species must be tentative until the ranges of variation of E. montanensis and E. wyomingensis are better known and until the status of the species E. silberlingi and E. superior is formally resolved. At present, the Big Bend specimens seem most similar to the northern species.

Family PERIPTYCHIDAE Cope, 1882
Genus PERIPTYCHUS Cope, 1881
Periptychus COPE, 1881, p. 484
PERIPTYCHUS SUPERSTES Matthew, 1935
Fig. 25; Table 22
Periptychus superstes (Matthew), SIMPSON, 1935, p. 25
Periptychus rhabdodon superstes MATTHEW, 1937, p. 121

Type. AMNH 17181, left P_4-M_3, right P_4-M_2, from the Tiffanian of Colorado.
Material referred. 41274-1, shattered right P_4; 40147-4, right maxilla fragment with the lingual half of a premolar, either P^2, P^3, or P^4; -17, right maxilla fragment with M^1-M^2, both broken on the lingual side, and left mandible fragment bearing one molar with the cusps broken off the trigonid; 40537-59, broken left mandible with P_4-M_2; 41367-8, right

mandible fragment with talonid of M_1 and partly erupted M_2.
Comment. The M_2 of 41367-8 was erupting at the time of the animal's death. Only the trigonid was exposed. An X-ray showed that M_3 was developing.
Description. Both upper and lower premolar and molar primary cusps are vertically striated. The crescentic protocone of 40147-4 is worn so that it is not possible to tell if a cuspule was present anterior to it, but a cuspule was present posterior to the protocone. On M^1 of 40147-17 the protostyle is broken off. The protocone lies anterior and slightly labial to the hypocone position. On M^2 of 40147-17, protostyle, protocone, and hypocone lie along a straight line.

The other lower teeth are similar in form to 40537-59 except as noted below. P_4 of 40537-59 is approximately two percent shorter than M_1 (table 22). On P_4 the paraconid, metaconid, a cusp on the posterolingual side of the metaconid, and a cusp on the posterolingual corner of the heel lie approximately in an anteroposterior line, with the metaconid slightly labial to the level of the other three cusps. M_2 of 41367-8 has many small cusps on the paracristid. Such cusps are absent on 40537-59, except for a single median cusp on M_2, probably because of wear. Length and width cannot be measured on 41274-1, but it was only slightly smaller than P_4 of 40537-59.
Discussion. Two species of Periptychus from beds of Torrejonian age have been named, P. carinidens (Cope, 1881a) and P. rhabdodon (Cope, 1881b), and one species of Periptychus from beds of Tiffanian age, P. superstes Matthew in Simpson (1935b) has been named. P. carinidens, P. rhabdodon, and P. superstes have been reported only from the San Juan Basin of New Mexico and Colorado. Simpson (1959, pp. 13-16) studied the Torrejonian Periptychus specimens in the American Museum of Natural History collections and concluded that all should be placed in P. carinidens, the older of the two names. Simpson (1935b, p. 26), in giving P. rhabdodon superstes Matthew specific rank, called it intermediate in tooth and jaw size between P. carinidens and P. rhabdodon and stated, "It seems to me as distinct from either P. rhabdodon or P. carinidens as they are from each other...." The characters used to distinguish P. superstes are that P. superstes has a more

elongate M_3 talonid and a smaller P_4 relative to the lower molars than *P. rhabdodon* or *P. carinidens* (Simpson, 1935b, p. 26). Too few specimens of Tiffanian periptychids have been reported to make possible evaluation of the importance of these characters. The fact that the only Big Bend specimen on which one of these characters can be observed, 40537-59, has P_4 proportionally shorter compared to M_1 than P_4 of the *P. superstes* type specimen (table 22) strengthens the possibility that there is a trend in reduction of P_4 size. Direct comparison of 40537-59 and the type of *P. superstes* revealed no significant difference in form.

Gazin (1938, p. 276) considered protocone position to be a primitive character of *Periptychus gilmorei* of the Puercan Dragon fauna in separating it from the younger *P. carinidens.* In *P. gilmorei* the protocone lies labial to the hypocone and protostyle position (Gazin, 1938, p. 276), as it probably did in M^1 of 40147-17 from eastern Tornillo Flat.

It is unlikely, however, that the protocone position on M^1 of 40147-17 is a significantly primitive character, because *Periptychus* in the American Museum of Natural History from the Nacimiento Formation, San Juan Basin shows considerable variation in the position of the protocone relative to the hypocone and protostyle. Some have the protocone labial to the hypocone and protostyle position in M^1-M^2, some have it in line, and some have one condition on M^1 and the other on M^2.

Wilson (1967, pp. 160-161) assigned the Big Bend *Periptychus* specimens from eastern Tornillo Flat to *P. carinidens,* and 40537-59 from western Tornillo Flat to *P. superstes.* No upper teeth of *P. superstes* have been reported in the literature. The only tooth from eastern Tornillo Flat which is directly comparable to one from western Tornillo Flat is the 40147-17 broken lower molar. It is approximately 40 percent smaller than M_2 of 40537-59, a difference which, for a single mathematical population, would yield a V of eight (Simpson *et al.,* 1960, p. 212). Comparing the lower limit to the upper limit of the observed range of *P. carinidens* from the San Juan Basin (Simpson, 1959a, table 4) for length of M_1 yields a 27 percent difference and for length of M_2 yields a 32 percent difference. The fact that a large *Periptychus* P_4, specimen 41274-1, was found approximately 21 meters from

the base of the formation on western Tornillo Flat (tables 1, 2), a locality which I consider to be older than the eastern Tornillo Flat locality on paleontological grounds (p. 43), indicates that the large and small *Periptychus* in Big Bend were contemporaneous. I consider the eastern Tornillo Flat locality to be Tiffanian and not greatly different in age from the levels on western Tornillo Flat from which large specimens (40537-59 and 41367-8) were recovered. Because nothing is known about the range in size of *P. superstes,* I will consider all the Big Bend *Periptychus* to belong to one species for now.

Order PANTODONTA

Some skeletal material which probably belongs to this order has not been included in the following lists of material and discussions. Many large bones in the TMM Black Peaks collections are covered with thick barite or calcite crusts (pp. 8-9) and have not been prepared. Only a few complete limb bones and ones associated with teeth and skull fragments are included in the following discussions.

I believe that sexual variation is more important in the Pantodonta than some previous authors assumed. Features which I believe may be affected by sexual dimorphism include: strength of an anteroexternal flange on the mandible, length of mandible symphysis, size and shape of canines, and overall size.

I attempted to use the log-ratio diagram method as used on pantodonts by Simons (1960, pp. 73-74) in comparing the Texas specimens with those for which Simons provided measurements. I found this method to be of little help. For example, close examination of Simons's figure 9 shows that striking differences in pattern occur within genera and families. Addition of non-barylambdid genera to this diagram reveals that some of them resemble some of the barylambdids more closely in log-ratio pattern than other barylambdids. Log-ratio plotting of data on small numbers of individuals will be more helpful with pantodonts when more information is available on range of variation and on the types of variation produced by sexual dimorphism. More specimens will be needed before consistent patterns emerge.

Family PANTOLAMBDIDAE Cope, 1883
Genus *CAENOLAMBDA* Gazin, 1956
Caenolambda GAZIN, 1956, p. 48
CAENOLAMBDA sp.
Figs. 26, 33; Table 23

Material referred. Specimen 41377-1, recovered in quarrying, includes both toothless mandibles, loose badly worn teeth, and scraps of the skeleton of one individual (fig. 33). The available teeth are: right upper canine, two left upper premolars, one right upper premolar, two incisors, left lower canine, left P_2, left P_3, right P_4, left M_1, right M_1, right M_2, left M_3, right M_3.

Description. The symphysis of specimen 41377-1 was fused, and the mandibles possessed a strong anteroexternal flange. The P_1 alveolus is anteroposteriorly elongate, and there is no diastema posterior to it.

The upper canine of 41377-1 is oval in cross section at its base. It has a rounded posterior projection and a wear facet on its posterointernal and anterointernal faces. The posterointernal facet bears prominent vertical wear striations. The lower canine is circular in cross section at its base, and it has a wear facet on its posterointernal and anterointernal faces. The incisors are circular in cross section at the enamel line. The protocone is centered on the transverse axis of the upper premolars. The upper premolars have a distinct precingulum on the anterior side of the protocone, but the posterior sides are too worn to determine if one was present there.

Discussion. The mode of occlusion of the upper canine with an anteroposteriorly elongated shearing P_1 in *Caenolambda jepseni* has not yet been found in any other pantodont (Simons, 1960, p. 24). Although no P_1 is available from 41377-1, wear facets on the upper and lower canines and the position and shape of the P_1 alveolus strongly suggest that 41377-1 had a P_1 similar to that of *C. jepseni.* Direct comparison reveals nothing in 41377-1 which would preclude its originally having resembled PU 14863, type specimen of *C. jepseni,* in form, although the extreme wear on the teeth of 41377-1 prevented the comparison of some diagnostic features. Specimen 41377-1 is approximately 40 percent smaller in length from the posterior edge of the canine alveolus to the posterior edge of the M_3 alveolus than PU 14863.

The canines of PU 14863 have facets similar to those on the canines of 41377-1, and they have similar wear striations on the posterolingual facet of the upper canine. The large posterolingual facet on the upper canine formed by wear against P_1, and the anterolingual facet formed by wear against the posterolingual face of the lower canine. The anterolingual facet on the lower canine must have formed by wear against an upper incisor. The posterior angle of the mandibles is similar in both PU 14863 and 41377-1. The anteroexternal flange of PU 14863 is stronger than that of 41377-1.

Other caenolambdid characteristics of 41377-1 include the lack of a diastema posterior to P_1 such as that seen in *Pantolambda,* the absence of forward rotation of the upper premolar protocones such as that seen in *Titanoides,* and the presence of upper premolar basal cingula which are lacking in the Barylambdidae (Simons, 1960, pp. 21, 23, 26).

The two known species of *Caenolambda* are *C. jepseni* and *C. pattersoni,* which is less than 15 percent smaller than *C. jepseni* in measurements on upper teeth (Simons, 1960, p. 74; Gazin, 1956a, p. 50). *C. pattersoni* has been reported from the early Tiffanian Bison Basin locality (Gazin, 1956a, pp. 49-50), and *C. jepseni* has been reported from a level in the Polecat Bench Formation, Big Horn County, Wyoming, with an associated fauna which suggests an age at the Torrejonian-Tiffanian boundary (Simons, 1960, p. 24). The level in the formation at which 41377-1 was found (fig. 34), 27 meters below the level of the early Tiffanian Ray's Bonebed, and its associated fauna indicate that it is probably close to the Torrejonian-Tiffanian boundary in age (p. 43).

The difference in size between 41377-1 and the *C. jepseni* type precludes its being placed in *C. jepseni,* which it resembles closely in form as far as can be determined. Little is known about the range of variation in size of *C. jepseni.* The extreme worn condition of the teeth of 41377-1 makes its designation as a new species unwise.

Family BARYLAMBDIDAE Patterson, 1939
Genus *BARYLAMBDA* Patterson, 1937
Barylambda PATTERSON, 1937, p. 229
BARYLAMBDA JACKWILSONI n. sp.
Fig. 27a-c; Tables 24, 25

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Type. 40537-83, left mandible with P$_3$-M$_3$ and symphysis, from Tiffanian Ray's Bonebed, Black Peaks Formation, western Tornillo Flat, Big Bend National Park, Texas.

Etymology. This species is named for Dr. John A. (Jack) Wilson in gratitude for his help during the years he has been my advisor. Dr. Wilson was the first to describe early Tertiary mammals from Tornillo Flat (Wilson *et al.,* 1952).

Hypodigm. 40536-156, left ?P^3 without labial side, labial half of left M^1 or M^2; -173, right mandible fragment with roots of P^4 and M^1 lacking labial edge; -117, crushed right M$_1$ or M$_2$; 40537-72, posterior half of right P$_2$ or P$_3$.

Diagnosis. Barylambda jackwilsoni is approximately 25 percent smaller than *B. faberi. B. faberi* upper molar protocones are less square than those of *B. jackwilsoni,* and they have cingula on the protocone which *B. jackwilsoni* lacks.

Description. The upper premolar is triangular. It has uninterrupted pre- and postprotocristae. A very faint cingulum is present on the anterior side; the posterior side is too crushed to determine whether or not a cingulum was present.

The lingual side of 40536-173 is squared, and the posterior edge of the tooth is concave. The protocone is not rotated posteriorly, but lies lingual to the paracone. There is no trace of a cingulum on the posterior or lingual sides of the tooth, and only a few tiny crenulations on the anterior side of the protocone. A paraconule is present. If a metaconule was present on the unworn tooth, it was smaller than the paraconule, because no metaconule is detectable now. The upper molar of 40536-156 is similar to 40536-173 as far as can be determined.

The type has a long procumbent symphysis and a small canine alveolus. The canine socket did not protrude labially. On the premolars, the paraconid is directed anteriorly and the metaconid is directed posteriorly. On premolars, the cristid obliqua is directed posterolingually. Molar trigonids are longer anteroposteriorly and wider than the talonids. Molars have metastylids which extend onto the talonid. The posterior angle of the jaw is not reduced. The posteroventral corner of the mandible extends downward and posteriorly, joining the ascending ramus at approximately a 70-degree angle.

Discussion. The Big Bend material exhibits most of the diagnostic barylambdid characteristics as described by Simons (1960). The Big Bend upper premolar has an uninterrupted postprotocrista, unlike members of the Titanoideidae. The upper molar differs from those of any of the Pantolambdidae in lacking a well developed cingulum on the protocone. The metaconid is directed posteriorly and the paraconid anteriorly in P$_2$-P$_4$ of barylambdids (Simons, 1960, p. 26) as they are in P$_3$-P$_4$ of 40537-83. Lower molars of Titanoideidae, unlike those of 40537-83, lack metastylids (Simons, 1960, p. 31). The longest and most horizontal symphyses, such as that of 40537-83, are found in the Barylambdidae; the most vertically-positioned symphysis occurs in *Titanoides,* in which the symphysis may not fuse until late in life (Simons, 1960, pp. 31, 45).

The North American genera of the Barylambdidae include *Barylambda, Haplolambda, Leptolambda,* and *Ignatiolambda.* In *Ignatiolambda* the lower canine is angled outward, forming a distinctive squared anterior jaw margin (Simons, 1960, p. 30). *Leptolambda* and *Ignatiolambda* have the cristid obliqua of P$_3$-P$_4$ oriented parallel to the tooth row instead of directed posterolingually as in *Barylambda* (Simons, 1960) and in 40537-83. The apparent orientation of the cristid obliqua varies with wear, so it is a characteristic on which I do not place much weight. All of the barylambdid genera except *Barylambda* have strong cingula on M^1-M^2. Only *Barylambda* has a strongly concave posterior edge on upper molars like that of 40536-173.

Direct comparison of 40537-83 was made with a cast of the *B. faberi* type mandible (CNHM 14637), with a cast of CNHM 14944, a lower jaw of *B. faberi* also from the Plateau Valley beds of Colorado, and with PU 16445, a mandible of *Haplolambda quinni* from the Silver Coulee beds of the Polecat Bench Formation of Wyoming, the only North American species of *Haplolambda* yet named. The dentition of 40537-83 is very similar in form to that of *B. faberi.* Specimen 40537-83 is 23 percent shorter in length from the anterior side of P$_3$ to the posterior side of M$_3$ than PU 16807, which is a cast of CNHM 14944. Specimen 40537-83 is only slightly larger than the *Haplolambda* specimen (table 25).

The 40537-83 molar talonids are transversely narrower than the trigonids, a condition differing from that of *B. faberi* but like that of *H. quinni.* In symphysis length and in size of M_3 relative to the other molars, 40537-83 resembles *B. faberi* instead of *H. quinni,* which was described by Patterson (1939, p. 365) as having M_3 proportionally smaller in comparison to the other molars than *Barylambda.*

Shorter length of symphysis was one of the characteristics used by Patterson (1939, p. 365) to distinguish *Haplolambda* from *Barylambda.* I believe that the long symphysis on 40537-83, longer proportionally than that of the larger *B. faberi,* indicates that specimen 40537-83 was a male. When the possibility of sexual dimorphism is taken into account, the major differences between *Haplolambda* and *Barylambda* are in the upper dentition, in which the Big Bend specimens most closely resemble *Barylambda.*

The shape of the protocone of the Big Bend upper molar is unique, but its form is most closely approximated in *B. faberi.* A direct comparison with a cast of CNHM 14637, type of *B. faberi,* shows that *B. faberi* upper molar protocones differ from 40536-173 in being less squared and in having a distinct but not strongly developed cingulum. *Barylambda faberi* is the only previously named species of *Barylambda,* and it has been reported only from the Plateau Valley fauna of the De Beque Formation, Mesa County, Colorado.

BARYLAMBDA sp.
Fig. 27d

A single worn lower premolar, 41221-11, and a femur, 41221-1, were found associated in float at the 137-meter level in the formation on western Tornillo Flat. The tooth is similar in form, as far as can be determined, to P_4 of 40537-83, type of *B. jackwilsoni.* The tooth is 17.1 mm in length and 15.4 mm in width. Since there is not enough barylambdid material at this level for specific identification, I will not assign it to *B. jackwilsoni* despite the similarity of the tooth. The occurrence of these specimens at the same level as the specimen of *Hyracotherium angustidens* gives them considerable stratigraphic importance (pp. 43-44).

Family TITANOIDEIDAE Simons, 1960

Genus *TITANOIDES* Gidley, 1917
Titanoides GIDLEY, 1917, p. 431
Sparactolambda PATTERSON, 1939, p. 352
TITANOIDES ZEUXIS Simpson, 1937
Figs. 28, 29; Table 26
Titanoides zeuxis SIMPSON, 1937, p. 11

Type. AMNH 35201, left mandible with P_3, trigonids of P_4, M_2, and M_3, from approximately 305 meters above the Scarritt Quarry, Fort Union Group, Montana.

Material referred. 41217-1, fragmentary left half of skull with upper $C-M^3$, broken left mandible with canine root, P_1, P_2, trigonid of M_1, talonid of M_2, and M_3 without metaconid, left radius, left ulna, and first, second, and third metacarpals; -5, right P_4, maxilla fragment with crushed molar; 40535-79, right mandible fragment with M^2 and crushed M^3; -84, right P_3 or P_4; 40536-151, right M^1 or M^2 lacking paracone; -148, right mandible fragment with roots of P_3-M_3 and lingual half of M_2; -173, left maxilla fragment with M^2 lacking paracone and anterior half of M^3; -145, right M^1; -170, left M^3; -132, right M_3; -148, toothless mandible fragments including symphysis region; -150, anterior half of toothless right mandible; -147, fragment of left mandible with canine root; 40537-94, right maxilla fragment with P^4-M^3; -87, canine scrap with triangular cross section; -40, left P_3; -73, left P_3; -130, anterior half of toothless right mandible; 41366-14, left M_1 or M_2 trigonid; -41, left mandible fragment with crushed M_1 or M_2.

Description. The description of the upper dentition is based mainly on 41217-1 and 40537-94, but applies to other specimens unless otherwise stated. The upper canine of 41217-1 is approximately circular in cross section at the base. A small ridge runs down its posterolabial side. The only wear facet on the upper canine is on the anterior face. The P^1 is two-rooted. The P^2-P^4 have no basal cingula on the anterior sides of the protocones, but their preprotocristae are complete. The P^4 of 41217-5 has both a preprotocrista and a basal cingulum on the anterior side of the protocone. The crest joins the cingulum. Postprotocristae are lacking on Big Bend *Titanoides* upper premolars and a basal cingulum is present on the posterior side of the premolar protocones. This cingulum forms a prominent shelf on P^4. Upper premolar protocones are rotated

anteriorly so that they lie anterior to the transverse tooth midline. Upper molar protocones have weak basal cingula which sometimes do not extend across their lingual faces. The posterolabial corners on upper molars extend almost as far labially as the anterolabial corners.

The skull and mandible were broken and scattered by weathering, so some distortion must be expected. The upper and lower canines of 41217-1 lie labial to the rest of the tooth row forming squared anterolabial jaw corners. The anterior root of the zygomatic arch is above M^1. The jugal has a posterodontal flange against which the zygomatic process fits. The posterior end of the jugal is tapered. The nasals extend as far posteriorly as the posterior edge of M^3. They have a broad posterior expansion. The transverse axis of the glenoid fossa is in a horizontal plane and is approximately perpendicular to the anteroposterior axis of the skull. Part of a stout paroccipital process of the exoccipital is preserved.

The mandible of the Big Bend *Titanoides* has a moderate anteroexternal flange. On specimen 40537-130 the mandibular symphysis had not fused; on other specimens breakage or weathering make this characteristic hard to judge. There is a large mental foramen below the space between the canine and P_1. The lower canine of 41217-1 is subcircular in cross section at the base; it had no posterior flange. The lower canine of 40536-147, on the other hand, is oval in cross section at the base and is 50 percent longer than it is wide. P_1 is two-rooted. The cristid obliqua of P_2-P_4 is directed posteriorly. On P_2 the metaconid is only slightly larger than the paraconid, and the metaconid is located approximately two-thirds of the distance back from the anterior tooth edge. The P_3s and P_4 have proportionally larger metaconids located approximately at the anteroposterior midpoint of the lingual side of the teeth. The M_3 has a strongly projecting hypoconulid.

Discussion. The dentition and the mandible form described above are characteristic of the genus *Titanoides* as described by Simons (1960), except in canine form, in presence of complete preprotocristae on some of the P_2-P_4, and in lack of a strong basal cingulum on the anterior side of some P_2-P_4 protocones. According to Simons (1960, p. 31) the

form of the lower canine, triangular at the base with varying development of a posterior blade, is unique in the Titanoideidae. Specimen 40537-87, a scrap showing a triangular tooth cross section, is the only Big Bend *Titanoides* canine with this characteristic. It is possible that specimen 41217-1, in which the upper canine lacks wear facets on the posterior side and the lower canine lacks a posterior blade, is a female, and that there was some sexual dimorphism in Big Bend *Titanoides* canines. Although Simons (1960, p. 43) gives interruption of the preprotocrista on upper premolars as a *Titanoides* characteristic, he states that some trace of the preprotocrista is usually present. Upper premolars of *T. majus* and *T. zeuxis* have not been described, so it is possible that they have stronger preprotocristae than the other previously described species of *Titanoides.* The Big Bend specimens' lack of a postprotocrista on upper premolars is a more important *Titanoides* characteristic (Simons, 1960, p. 43). The partial skull of 41217-1 is similar to those described by Simons (1960) for *Titanoides,* except for the orientation of the glenoid fossa. The transverse axis of the glenoid fossa is oblique to the anteroposterior axis of the skull with the external end of the fossa directed anterolaterally in previously described *Titanoides* and all the pantolambdoid species (Simons, 1960, pp. 41-42), whereas in the Big Bend specimen it is perpendicular to the anteroposterior axis of the skull.

The genus *Titanoides* includes five species: *T. primaevus, T. zeuxis, T. gidleyi, T. majus,* and *T. simpsoni.* For three of these species, *T. zeuxis, T. majus,* and *T. simpsoni,* the available material is very scanty, and the differences in form of dentition on which all except *T. simpsoni* are based are small (Simons, 1960, pp. 33-39). *T. simpsoni* has M^3 smaller in proportion to M^1-M^2 and it has a smaller protocone on upper molars than other *Titanoides* species. *T. majus* is larger than *T. primaevus* or *T. gidleyi* (Simons, 1960, p. 38). In *T. gidleyi,* M^3 is much larger in proportion to the rest of the molars than it is in *T. primaevus,* and in *T. primaevus* it is proportionally larger than in the Big Bend specimens. The Big Bend specimens are similar to the larger *T. primaevus* in form, except for the minor differences in the upper premolar protocones described above and in the form of P_2. The P_2

of *T. primaevus* has a proportionally larger metaconid, which is situated on the antero-posterior midpoint of the lingual margin of the tooth (Simons, 1960, p. 37), like the metaconid of the Big Bend *Titanoides* P_3-P_4.

T. zeuxis, the smallest *Titanoides* species, is similar in proportions to *T. primaevus* (Simons, 1960, p. 36). The Big Bend *Titanoides* is similar in size to *T. zeuxis.* Length of P_2 of 41217-1 is three percent less than one and 18 percent less than the other P_2 measurement for *T. zeuxis* given by Simons (1960, p. 76). This size difference is not significant; for example, P_4 of 41217-1 is 16 percent smaller in width than 41217-5, P_4 of another individual from approximately the same level in the formation. Specimen AMNH 35201, the *T. zeuxis* type specimen, is badly weathered, so even in direct comparison it is difficult to evaluate its features. The available teeth of AMNH 35201, P_3 and M_3, for which comparable Big Bend material is available, do not appear to differ significantly. At least one *T. zeuxis* lower canine had a posterior blade according to Simons (1960, p. 36), and at least some Big Bend specimens lacked one. The P_2 of *T. zeuxis* has subequal paraconid and metaconid (Simons, 1960, p. 37) as does the Big Bend P_2. The only upper tooth previously referred to *T. zeuxis* is a single upper premolar which Simons (1960) mentions but does not describe, and no part of the *T. zeuxis* skull was previously known. The small differences between the Big Bend specimens and previously described *Titanoides* do not justify proposing a new species for them, especially considering the number of poorly known species which are already in existence.

Except for *T. simpsoni* from the Torrejonian Gidley Quarry of Montana, all the species of *Titanoides* have been reported from levels similar to or younger than the Tiffany fauna (Simons, 1960, table 1). *T. zeuxis* has been reported from the Melville Formation in Montana, 305 meters above the Scarritt Quarry level, and from the Plateau Valley fauna of Colorado. The Big Bend specimens represent a downward extension of range from the Clarkforkian to the Tiffanian.

Order PERISSODACTYLA
Family EQUIDAE Gray, 1821
Genus *HYRACOTHERIUM* Owen, 1840
Hyracotherium OWEN, 1840, p. 163

Pliolophus OWEN, 1858, p. 54
Eohippus MARSH, 1876, p. 402
Protorohippus WORTMAN, 1896, p. 92
HYRACOTHERIUM ANGUSTIDENS
Fig. 30; Table 27

Kitts (1956, p. 35) provides a synonymy of *H. angustidens.*

Type. USNM 1079, mandible fragment with M_1-M_3, from the Almagre member, San Jose Formation, Wasatchian of New Mexico.

Material referred. 41221-8, maxilla fragment with left M^1-M^3.

Description. The three teeth are very similar in form. All have a strong conical hypocone. Their transverse width is only slightly greater than their length. The protoloph joins the paracone on its anterior side. The metaloph is weaker than the protoloph, but it reaches the anterolingual side of the metacone. An ectoloph and a strong parastyle are present on all three teeth. All three have paraconules, and M^3 shows a worn area which may have been a metaconule, but the metaconule is absent on M^1 and M^2.

Strong cingula encircle the teeth. They are complete except on the lingual side of the hypocone on M^1. All three teeth show a weak mesostyle on the ectocingulum. This mesostyle is strongest on M^1. The postcingulum is broader on M^3 than on M^1 or M^2. The postcingulum on M^3 is wrinkled and bears a strong cuspule posterior to the metaconule position.

Discussion. In his revision of the genus *Hyracotherium,* Kitts (1956) reduced the number of American species to three, *H. angustidens, H. vasacciense,* and *H. craspedotum.* Kitts (1956, p. 55) considered early Wasatchian *H. angustidens* to be more primitive than the late Wasatchian *H. vasacciense* and *H. craspedotum* and almost certainly ancestral to them. Jepsen and Woodburne (1969) have described a single lower jaw from the upper part of the Polecat Bench Formation (late Paleocene) as *Hyracotherium* cf. *H. angustidens.* Since 1956 one new American *Hyracotherium* species has been added, *H. seekinsi,* named by Morris (1968) and described as closely related and possibly ancestral to *H. angustidens. Hyracotherium* specimens from the Hannold Hill Formation, Big Bend National Park, Texas (pp. 3-4) have been referred to *H. vasacciense* (Wilson, 1967, pp. 166-167).

Differences in P^3,P^4, and M_3, teeth which

are not yet available from the Black Peaks Formation, were used by Kitts (1956) to separate the three species he recognized. Specimen 41221-8 is referrable to *H. angustidens* or *H. vasacciense,* the small hyracotheres (Kitts, 1956), on the basis of tooth size. The teeth fall within size ranges for length and width given by Kitts (1956, table 14) for *H. vasacciense.* M^1 of 41221-8 is smaller than any *H. angustidens* described by Kitts (1956, table 4), but M^2 and M^3 fall within the *H. angustidens* range. V for anteroposterior length of M^1 in a population containing both 41221-8 and the largest *H. angustidens* from the Almagre member of the San Jose Formation reported by Kitts (1956, table 4) is less than five.

Specimen 40143-14 from the Hannold Hill Formation in Big Bend National Park has been placed in *H. vasacciense,* because of the form of its P^3 (Wilson, 1967, p. 167). Before this P^3 was discovered, when M^1-M^3 and P_4-M_3, but no upper premolars, were available from the Hannold Hill Formation, Kitts (1956, p. 54) considered it referrable to either *H. angustidens* or *H. vasacciense.* The main difference in form between 40143-14 and 41221-8 is that M^1 and M^2 of 40143-14 have a metaloph which splits into two branches, one reaching the metacone and one reaching the metaconule.

In *H. seekinsi,* M^1-M^2 are smaller and wider in proportion to length (more rectangular in the terminology of Morris) than those of *H. angustidens* (Morris, 1968) and of 41221-8 (fig. 30). Morris (1968, p. 7) considered the paracone and metacone of M^2 to be closer together in *H. seekinsi* than in *H. angustidens* and suggested desmatoclaenid ancestry for *H. seekinsi.* The M^2 of 41221-8 resembles *H. angustidens* in paracone and metacone position and in shape of the anterolabial corner. M^3 of *H. seekinsi* has three small cusps in the hypocone region, one of which is on the lingual cingulum (Morris, 1968, p. 6), unlike M^3 of 41221-8 which has a single well-developed hypocone with the cingulum continuous on its lingual and posterior sides. Both *H. seekinsi* and 41221-8 occur with barylambdid pantodonts (table 2, p. 186, fig. 34) in southern faunas; however, despite the stratigraphic and relative geographical closeness of *H. seekinsi* and the Big Bend *Hyracotherium,* differences in form rule out placing 41221-8 in *H. seekinsi.*

PALEOENVIRONMENT
ENVIRONMENT OF DEPOSITION

Depositional processes which formed facies within the Black Peaks Formation were determined through comparison with recent depositional systems. The model most analogous is the fine-grained meander belt model (Fisher *et al.,* 1969; W. L. Fisher and A. J Scott, oral communication, 1969). Characteristic of this model is the high percentage of mud, approximately 60 percent by volume, compared with sand and gravel. In this model, most sand is deposited by laterally accreting point bars. The scale of bedding and the grain size decreases, although not regularly, upsection in the point bar deposits. These point bar deposits are preserved in sand bodies up to 15 kilometers wide. The rivers change channels by avulsion (crevassing into the lower flood basin), allowing overbank deposits to cap abandoned sand-rich meander belts. Point bar, levee, and flood basin deposits grade into one another. Overbank deposits, mainly mudstones, are usually much disturbed by roots and thus seldom show sedimentary structures. Deposition of fine-grained meander belt sediments takes place under low gradient on the portions of alluvial plains distal from the source.

The thick sandstone bodies in the Black Peaks Formation (fig. 7) are channel and point bar deposits, whereas the mudstone is an overbank deposit, deposited on the levees, in abandoned channels, and in the flood basin. The thin sandstone layers within the mudstone are crevasse splay deposits formed when breaks in the levee allowed bed load to splay out into the floodplain.

The geometry of the sandstone bodies in the mudstone and a sequence of bedding and grain size changes which is typical of point bar deposits indicate that these sandstone bodies were laid down by meandering rivers. Much of the lower portions of the thick sandstone layers were deposited when the rivers were in flood and scoured their deepest. Sand waves filled the scours to form the trough cross bedding. Point bar deposits accreted laterally as the main channel meandered, so that they now lie above the fill of the deep scours in the sandstone layers (fig. 31). High flow-regime conditions, reached when flood waters streamed across the point bars, pro-

duced low angle sets of planar beds. Rain wash on the subaerially exposed point bar reworked some of the sandstone deposited there to form planar, nearly horizontal layers. Some structures, such as ripple cross bedding and the shallow trough cross beds produced as sand waves migrated across irregular but not deeply scoured surfaces, formed on point bars under low flow-regime conditions as the floods waned.

Mudstone was deposited when suspended load settled out forming clay drapes. Locally, flood waters winnowed nodule pieces, bone scraps, and small teeth out of mudstone to form small conglomerate lenses (table 2). The clay drapes left by floods were thin, probably seldom over five centimeters thick in the flood basin. Mansfield (1938, p. 70) reported that clay drapes ranged from 0.25 inch (0.6 cm) to two inches (5 cm) thick one-quarter mile (½ km) from the Ohio River after the floods of 1937. The levee environment graded into the flood basin environment, and both received overbank sediments. Mudstone formed near the channels would contain more silt, sand, and clay clasts than flood basin deposits. The levees were probably the areas of highest elevation during the Paleocene, and thus levee sediments were better drained and oxidized than flood basin sediments.

The color layers so prominent in the mudstone today (fig. 6) are not sedimentation units but are the results of soil-forming processes (pp. 42-43). Sedimentary structures were destroyed by the activities of animals, the movement of roots, erosion, weathering, leaching, and compaction in the mudstones.

PALEOGEOGRAPHY

There is evidence for gradual regional uplift of the Big Bend region in the Late Cretaceous and Paleocene. Some regional uplift took place between the period of deposition of the tidal flat deposits of the lower Aguja Formation and the fluvial deposits of the upper Aguja Formation (Hopkins, 1965). A gradual change in paleoslope also took place. The direction of transport for the Aguja Formation was to the north-northeast toward the late Cretaceous interior seaway which extended from the Arctic southward (Hopkins, 1965, p. 108). The average direction of trans-

port of the Javelina Formation was to the east and southeast (Lawson, 1972, p. 40). The direction of transport of the Black Peaks Formation was to the south or southeast.

Despite the small areal extent of exposures, the position of the Black Peaks fluvial deposits relative to Paleocene highlands and the sea can be roughly deduced from sedimentological evidence. Petrological evidence suggests that some material from the Javelina Formation, the Aguja Formation, and perhaps even older Cretaceous formations may have been reworked into the Black Peaks Formation; however, these formations could not have been exposed in local highlands. Uplifts exposing those older formations either lay to the west outside the Big Bend region, or were so gradual that they had little topographic expression. The presence of high relief near western Tornillo Flat is unlikely. The Black Peaks mode of deposition and scarcity of gravel-sized detritus indicate a low gradient in the area of deposition. The environment of deposition of the Black Peaks Formation must have been the portion of an alluvial plain distal to the source and probably not far from the deltaic environment. The nearest Paleocene deposits to the south and southeast are marine (p. 2), so the deltas fed by the Black Peaks rivers have been eroded away. The deltaic environment would have differed from that in which the Black Peaks Formation was deposited in having distributary channels of lower sinuosity than the meandering rivers which deposited the Black Peaks Formation and in having marshes in which lignite formed (Fisher *et al.,* 1969, pp. 15, 18, 20-21).

Information on plate tectonics gives a picture of the worldwide distribution of land and sea in the Paleocene. The latitude of the Big Bend region in the Paleocene was somewhere between 25-35 degrees North. Sloan (1969, fig. 4; this paper, fig. 32) shows Big Bend at approximately lat. 35 degrees North with the North Pole at the Late Cretaceous position; Szalay and McKenna (1971, fig. 2) show it at approximately latitude 25 degrees North with the North Pole at its late Paleocene position. Since the Big Bend region is presently at approximately latitude 30 degrees North, there is little or no difference in the paleolatitude and its present position. According to Pitman and Talwani (1972, pp. 637-638), during the Paleocene the Greenland and Norwegian seas

were closed at the north end, and North America and Europe were contiguous. Asia was separated from Europe by the Turgai Straits, and its connection to North America, via the Bering Straits, was further north than the North America-Europe Paleocene connection (Szalay and McKenna, 1971, p. 284). At the beginning of the Tiffanian, the Cannonball Sea was retreating, but it may have still extended as far north as Wyoming (Sloan, 1969, p. 441).

Paleoecology

Taphonomy

Carcasses of most large animals, the size of *Phenacodus matthewi* or larger, appear to have undergone a period of exposure on the floodplain surface before burial. Bones often show evidence of having undergone weathering before burial. Crusts preserve split and flaked bones. Curls and chips of bone only partly attached to the shaft can be seen within nodular and concretionary crusts. Specimen 41377-1 (fig. 33), a partial skeleton of *Caenolambda,* which was quarried out of mudstone (tables 1, 2) must have been exposed quite awhile before burial. It occurred in a layer 10-15 centimeters thick. Both mandibles were present, but all teeth had fallen out. Most of the teeth were found scattered among the other bones and some bones had been broken before burial. The occipital condyle was the only part of the skull recovered. Only one foot showed some articulation.

The scattered distribution of fossils both vertically and horizontally suggests that the events determining their preservation were not catastrophic. The scarcity of articulated specimens, or even of associated material of single individuals, indicates that carcasses were seldom buried quickly. Although the floodplain was periodically flooded, the intervals of flooding usually represented relatively brief portions of the year (p. 43). Most carcasses exposed between floods would have been scattered or chewed up by scavengers and damaged or destroyed by weathering. Clark *et al.* (1967, p. 99) have named the total destructive processes acting on corpses as perthotaxy, and an assemblage of corpses unburied long enough to exhibit all stages of destruction, like that which must have occurred on the Paleocene floodplain in the Big Bend region, as a complete perthotaxis.

Chances of preservation were best in low, wet areas of the floodplain and near the channels. Hollows and areas near the channels were more frequently flooded and covered with thicker clay drapes than the rest of the flood basin. Specimen 41217-1, *Titanoides zeuxis,* has been damaged by recent weathering, but the skull, jaws, and one leg were probably preserved articulated. The specimen was found in place in mudstone capping a channel sandstone (table 2). The channel had been abandoned either through meander cutoff or avulsion leaving a hollow which must have been, at times, a small pond. Ray's Bonebed and Ray's Annex (table 1) are the areas of fossil concentration where exposures are best to examine facies relationships. Both are in floodplain mudstone which grades horizontally into levee and point bar deposits associated with a large channel about 0.4 kilometers away to the north. The bonebed areas were low spots behind the levee. These areas were more frequently flooded than areas farther from the channel, and they stayed wetter. More fossils, therefore, were buried by clay drapes or sank into soft mud and were preserved before complete destruction. Little reworking of sediment took place at Ray's Bonebed. Lack of concentrations which are produced by reworking may account for the failure to recover many small mammal teeth by washing at Ray's Bonebed. A greater abundance of gar scales, ray teeth, and pelecypod shells are found at Ray's Bonebed than is usually seen in Black Peaks floodplain sediments, indicating that small ponds may have been present occasionally. Gar may have been trapped in such ponds. Pond conditions never persisted long enough to produce pond deposits recognizable as such. For example, the bonebed area does not show more black mudstone, colored by organic matter, than nearby unfossiliferous sediment and it does not show sedimentary structures such as laminations which would have formed in quiet ponds. When the ponds dried, activities of animals and plants and slippage in the clay destroyed sedimentary structures just as they destroyed flood-formed sedimentary features elsewhere on the floodplain. Most disarticulation of the bones was probably caused by the activities of animals and plants.

Most fossil animals have not been trans-

ported far from the area of their death. Most carcasses on the floodplain would have decayed beyond the state at which they would float at the onset of a flood. There is no evidence that bones and teeth have been transported far. Bone is scarce in channel sandstones, except for fragments among the gravel-sized material in the bases of scours. At the bonebeds, there is no evidence of mechanical concentration or size sorting of fossils except in the conglomerate lenses, which seldom include material larger than two centimeters in diameter. For example, 40537-88, a single *Tricentes truncatus* molar, was found in place in mudstone about two centimeters from the side of 40537-83, a *Barylambda jackwilsoni* mandible, at Ray's Bonebed. Some of the small teeth found in conglomerate lenses such as those at Joe's Bonebed (fig. 8) are water-worn. This wear took place during transport on the floodplain during floods. Most teeth were not transported in the main channels and then washed into the flood basin, because the tooth-rich conglomerates are composed of carbonate nodule pieces in mud matrix and contain little sand. Joe's Bonebed conglomerate (locality 41365), for example, is a muddy granule conglomerate, in the terminology of Folk (1968, pp. 28, 29). Currents strong enough to carry the teeth away from the main channels would also have carried sand. The tooth-bearing conglomerates represent coarse material winnowed out of floodplain sediments by flood waters.

Paleoclimate

The Paleocene climate of the Big Bend region was semi-tropical to tropical, as shown by the flora (M. L. Abbott, 1973, pers. comm). The extremes of temperature and moisture-availability that characterize the area today were moderated by the greater nearness of the sea. The Black Peaks exposures now lie hemmed in by north-south trending mountains. In the Paleocene, the Big Bend area lay on an alluvial plain, with the sea much closer than it is today (p. 2; Rainwater, 1960). Moisture-laden ocean winds could reach the area without impediment. The fierce heat so characteristic of the dry, bare outcrops of the Black Peaks Formation in summer now would not have been reached in the vegetation-shielded and evaporation-cooled soils of the

Paleocene. The Paleocene rivers were not intermittent; therefore, they provided moisture for woods along their banks at all times. Crocodiles remained abundant throughout the deposition of the formation, so winters in the Big Bend region during the Paleocene must have been mild, without prolonged freezes.

I was unable to recover pollen from the formation (Schiebout, 1970, p. 61). Lawson (1972, pp. 48, 72) has described a pollen flora of 37 species, which he considers to be Paleocene, from a single locality in rocks belonging to the Tornillo Group (pp. 3-4) from the western part of Big Bend National Park. Dr. M. L. Abbott of Sul Ross State University in Alpine, Texas, is studying the fossil wood of the Black Peaks Formation. Plants identified from wood from the formation are mostly angiosperms, and include *Platanus* (sycamore), *Torreya* (stinking cedar), and a new genus of tree fern, but no palms (M. L. Abbott, 1972, pers. comm.). The wood lacks seasonal rings. Dr. Abbott's paleobotanical study may yield more detailed information on the Big Bend Paleocene climate.

The color layering seen in floodplain deposits throughout the formation (fig. 6) reflects variability of climate, with alternating relatively wet and dry periods of greater than seasonal duration. Differences in the amount of rainfall and the frequency and duration of flooding affected soil-forming processes and vegetation. Most color layers of mudstone were formed over a period of years. Probable yearly sediment increments were small (p. 39) in comparison to the thickness of these color layers which ranges up to six meters. Sediment addition by floods slowly raised the surface zone where alluvium was most actively affected by color-forming processes to produce the layering. No regular cyclicity of pattern and no trends of frequency of occurrence or thickness of color bands are discernible within the formation. The climatic variability continued throughout the period of deposition of the formation. This evidence for Paleocene climatic variability agrees with the results of several studies of North American floras which indicate that the Paleocene, in general, was warm temperate, cooler and less equable than the subtropical Late Cretaceous and early Eocene (Dorf, 1959, p. 185; Hall and Norton, 1967, p. 128; others listed by Sloan, 1969, p. 428).

Habitats

Conclusions regarding the specific habitat and ecological niche of species in the Black Peaks fauna cannot be drawn from the available information on fossil occurrence and environments of deposition. Most of the fossil concentrations found in place reflect sedimentary and preservational conditions and do not necessarily indicate that the areas in which they were found were part of the ordinary habitat of the animals, or that the animals were more common there than in areas where none have been preserved. Too few specimens are found in place for a correlation to be made of animals with facies and thus with habitats. Few remains of terrestrial animals are found in channels, so that it is unlikely that many of the Black Peaks animals were washed in from other regions (pp. 40-41). Sedimentological information on the environments of deposition of the Black Peaks Formation shows that a variety of habitats was available to the Paleocene fauna of Big Bend.

Rivers, constantly building and reshaping, dominated the Paleocene landscape of the Big Bend region. Their position determined the topography and distribution of vegetation, and the frequency and duration of their flooding affected overall soil and vegetation patterns. The work of Sioli (1951 a, b, c) in the Amazon Basin, in which he describes the physiographic provinces of Amazon Basin fluvial systems, provides analogs useful in interpreting the environmental conditions in Big Bend during the Paleocene. Clark *et al.* (1967) used Sioli's work in developing a model for analyzing fluvial sediments of the Scenic Member of the Oligocene Brule Formation in the South Dakota badlands, and I used a model based on the work of Sioli and Clark in detailed descriptions of the environment of deposition of the Black Peaks Formation on western Tornillo Flat (Schiebout, 1970).

The levees were the topographically highest areas on the Paleocene alluvial plain. Trees, some very large, lined the levees. Petrified wood is common on western Tornillo Flat. Silicified logs, for example, are very common in sandstone body 4 (fig. 3) in which over 50 logs occur along a four-kilometer-long exposure. The 44 logs on western Tornillo Flat on which size could be estimated averaged one meter in maximum diameter; the largest log in the Black Peaks Formation is 2.4 meters in maximum diameter (fig. 11). Most trees preserved in sandstone probably grew on the banks of the meandering rivers not far upstream from where they came to rest. They fell into the water as the river undercut its banks, and the dragging roots and branches of the large trees hindered transport by the shallow rivers, which were usually less than 12 meters deep (p. 6). Trees line the levee of the Amazon Basin rivers forming a gallery wood, and on the large rivers, kilometer-wide sections of the wooded banks crash into the river when undercut (Sioli, 1951c, p. 274).

Formation of the gray and black mudstone layers, which are colored by small amounts of finely disseminated organic matter, occurred when the ground was kept moist and vegetation was abundant. Reducing conditions were necessary for preservation of the organic matter, and they are responsible for the lack of calcium carbonate nodules in black mudstone layers. Some of the Paleocene flood basin, at times, may have resembled parts of the Amazon Basin described by Sioli (1951c, p. 279) where the forests are usually flooded with organic-rich "Schwarzwasser" (black water). The black mudstones contain more clay-size material than the red or gray mudstones. When floods met standing water, they quickly dropped their bed loads. Only very fine material could have been carried out into the flood basin under such conditions. The vegetation which left the black organic residue may have choked the basin, further impeding flow. Small lakes and swampy areas were always present, even in drier periods, if only in channels abandoned by avulsion or meander cut-off (table 2).

Red mudstone layers developed during a period of seasonal flooding when alluvium dried out and was oxidized between floods, when conditions were similar to that found in the *varzea* forest and grasslands of the Amazon Basin (Sioli, 1951c). Periodic flooding with carbonate-laden waters, followed by drying of the alluvium, led to formation of the carbonate nodules. The Amazon Basin *varzea* is dry in the summer, the dry season, and flooded in the rainy winters. Thin sections of wood from some fossil logs found in the Black Peaks Formation lack seasonal rings; however, many of these trees grew near the rivers (p. 41), so they would not have been

much affected by fluctuations in the availability of moisture on the floodplain. Sioli (1951c, p. 272) describes the *varzea* as a wide lowland with fruitful soil and states:

. . . dieses Varzea-Gelände . . . auch heute noch in senkrechter. Richtung durch ständig, bei jeder regenzeitlichen Überschwemnung wiederholte Sedimentation anwächst, welcher Vorgang von einer typischen Vegetationsfolge begleitet wird.

. . . this varzea region . . . still grows today in a vertical direction by continuous sedimentation which is repeated with each flood during the rainy season, the process of which is accompanied by a typical vegetation succession.

There is no way to determine the color of the clay when originally deposited on the floodplain. Color mottling indicates that color changes were reversible. For example, the decay of roots or other vegetation produced gray reduced patches in red, well oxidized soils. Sediment addition by floods raised the surface zone of active weathering, bioturbation, and frequent water penetration preventing color-forming processes from acting further on the sediment. Thus, varicolored mudstone layers reflected changing conditions.

In large floods, sheetflow may have covered most of the flood basin, locally reworking and concentrating nodules and fossils from the floodplain soil (table 2). No evidence of catastrophic effects of these floods on the fauna or flora has been discovered; most dead animals were disarticulated and decayed, their bones weathered and scattered over the ground surface, before burial by flood-deposited mud (pp. 40-41). The frequent climatic changes and their accompanying vegetation and soil differences produced gradual shifts in the proportions of various habitats. For example, in the drier periods the forests far from the rivers may have given way to savannah. A variety of habitats, including gallery forest, river, lake, and swamp would have been available at all times.

CORRELATION AND AGE
OF THE FAUNA

Figure 35 shows the distribution in North America of the mammals which are found in the Black Peaks Formation and some closely related to them. My listing of their occurrence at other localities is based on Russell (1967). Detailed discussions of age and range of each mammal from the formation are given in their individual descriptions (Systematic Paleontology). No radiometric ages are available for Black Peaks rocks. Statistical comparison of percentage faunal composition with other localities (Simpson, 1960) has not been attempted because of the low number of fossil mammals available at any one level in the formation (fig. 34).

The faunas of the three most prolific localities in the Black Peaks Formation, the eastern Tornillo Flat locality, Ray's Bonebed and Annex, and Joe's Bonebed, indicate a Tiffanian age for their levels on Tornillo Flat (fig. 34). Their closest affinities are with the Tiffany fauna of southern Colorado, perhaps, in part, because both are southern localities. I consider the similarities of the Black Peaks and Tiffany primates and the presence in the Black Peaks fauna of the multituberculate *Ectypodus musculus,* which has previously been reported only from the Tiffany fauna of Colorado, particularly important in arriving at this conclusion.

The lowest fossil level in the formation contains two animals not found higher in the formation, *Promioclaenus acolytus* and *Caenolambda. P. acolytus* has only been reported from the Torrejonian, and the Big Bend *Caenolambda* most closely resembles *C. jepseni,* approximately at the Torrejonian-Tiffanian boundary in age (Simons, 1960, p. 24). The Black Peaks lowest fossil level is best considered to be late Torrejonian or early Tiffanian, very near the Torrejonian-Tiffanian boundary.

Three teeth of *Hyracotherium angustidens* were found in association with barylambdid pantodont remains at the 137 meter (450 foot) level in the formation, only 50 meters stratigraphically above Joe's Bonebed and 30 meters above the level of locality 41364 which has yielded a taeniodont not older than Tiffanian, according to Patterson's (1949b) criteria (table 2). Joe's Bonebed and locality 41364 are approximately 1.6 kilometers along continuous outcrop from the *Hyracotherium* locality, 41221. *Hyracotherium seekinsi* was found with barylambdid pantodonts by Morris (1968) in Baja California, and Jepsen and Woodburne (1969) have reported a single specimen of *Hyracotherium* cf. *H. angustidens* from the upper part of the Polecat Bench Formation (late Paleocene) of Wyoming. I con-

sider the 137-meter (450 foot) level of the Black Peaks Formation to be of latest Paleocene (Clarkforkian) age (p. 3).

Geographic differences between the fauna from the Black Peaks Formation and the northern faunas from Montana and Wyoming are to be expected (fig. 32). Characteristics of early Tertiary southern communities as discussed by Sloan (1969, pp. 444-445) include: greater number of species, lower proportion of plesiadapoid primates, Hyopsodontinae less common and Mioclaeninae more common, and proportion and diversity of phenacodontid condylarths higher. Differences in number of species, of course, reflect the taxonomic practices of different authors, and may not indicate any real geographic difference. Because most of the Torrejonian and early Tiffanian localities are southern and the late Tiffanian and Clarkforkian localities are northern, the differences between northern and southern localities pointed out by Sloan (1969) are the result of age variations as well as geographic variations (figs. 35, 36). Sloan considers *Periptychus* and *Protoselene* to be restricted to southern faunas and *Titanoides* probably to be restricted to northern faunas. *Titanoides zeuxis* is the most abundant pantodont and one of the most abundant animals from the Black Peaks Formation. *Titanoides* can no longer be considered solely a northern animal. *Ectypodus musculus,* found only in the Tiffany and Black Peaks faunas, may be restricted to the south. The fauna of the Black Peaks Formation agrees with Sloan's generalizations in having a high proportion and diversity of phenacodontid condylarths, in including *Periptychus* and *Protoselene,* and in having only two plesiadapoid primates in comparison to the six species at the early Tiffanian Bison Basin localities in Wyoming (Gazin, 1956b).

Differences from the European Paleocene localities described by Russell (1964) are even more marked than the differences from northern localities, despite latitudinal similarity in the Paleocene (fig. 32). Only four of the 25 genera reported from Cernay, France, *Neoplagiaulax, "Berruvius" [Navajovius], Chiromyoides,* and *Arctocyon,* and one of the 13 genera from the Walbeck locality in Germany, *Arctocyon,* also occur in the Black Peaks Formation. These differences may result from geographical variation, differences in age, and hesitation of vertebrate paleontologists to use generic names imported from across the Atlantic.

SUMMARY

The fauna of the Black Peaks Formation is the southernmost large Paleocene fauna of North America. It includes 29 species of mammals belonging to 28 genera. The 170-meter (560-foot) thick formation contains three principal faunal levels. The lowest level is latest Torrejonian or earliest Tiffanian in age, the second is early Tiffanian, and the third is Clarkforkian.

The rocks composing the formation were deposited by meandering rivers. Thick sandstone bodies (3-12 meters) are channel and point bar deposits and the mudstone is an overbank deposit laid down during floods. During deposition the climate was semitropical to tropical with alternating wet and dry periods of greater than seasonal duration. Soil forming processes acting on overbank muds produced the color layering so prominent in the formation today.

At least three new species, a barylambdid pantodont, a multituberculate, and an insectivore, occur in the formation. The fauna is rich in condylarths (six genera) and primates (six genera). A specimen of the primitive perissodactyl *Hyracotherium angustidens* from the third level is the third *Hyracotherium* to be reported from rocks older than the Eocene.

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EXPLANATION

──┈─┈─ BIG BEND NATIONAL PARK BOUNDARY

─ᵁ─ FAULT ZONE

──┈──┈ INTERMITTENT STREAM

Other areas of exposure of Black Peaks Formation

☆ Northwest of McKinney Hills

★ South of Chisos Mountains in upper drainage of Juniper Draw
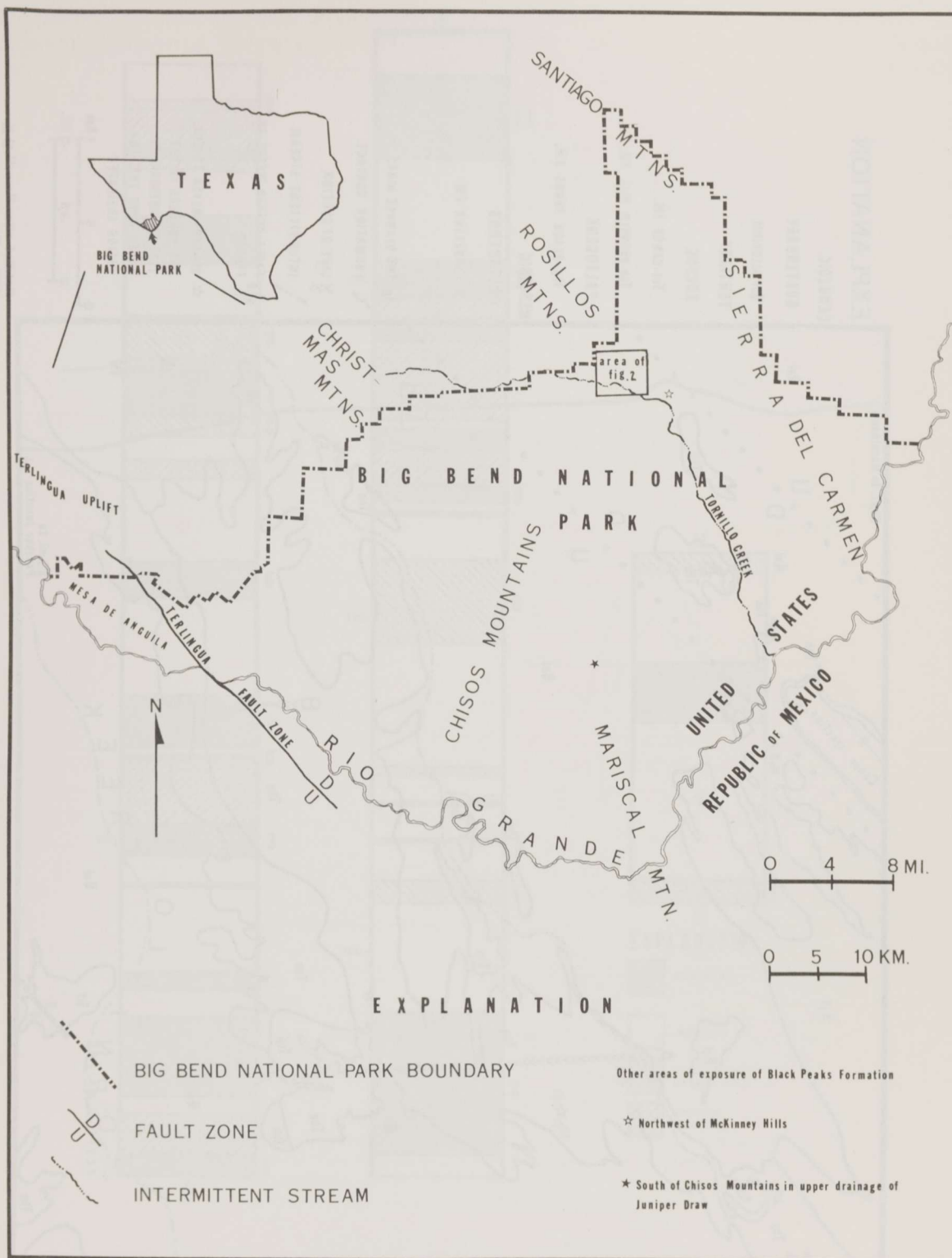
Fig. 1. Index map, Big Bend National Park, Texas

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EXPLANATION

CENOZOIC

QUATERNARY

Qal - ALLUVIUM

TERTIARY

EOCENE

Tcf - CANOE FM.

Thh - HANNOLD HILL FM.

PALEOCENE

Tbp - BLACK PEAKS FM.

MESOZOIC

CRETACEOUS

Kjf - JAVELINA FM

Ig - TWO DIABASE DIKES

FORMATION CONTACT

LINE OF SECTION

INTERMITTENT STREAM

FAULT, DOTTED WHERE IN-
FERRED

NUMBERS REFER TO FIG-
URE NUMBERS IN THE
TEXT OF PHOTOGRAPHS
TAKEN FROM THE LO-
CATION INDICATED

Modified after Maxwell, et al.
(1967, pl. II)

Fig. 2.—Geologic map, western Tornillo Flat, Big Bend National Park, Texas
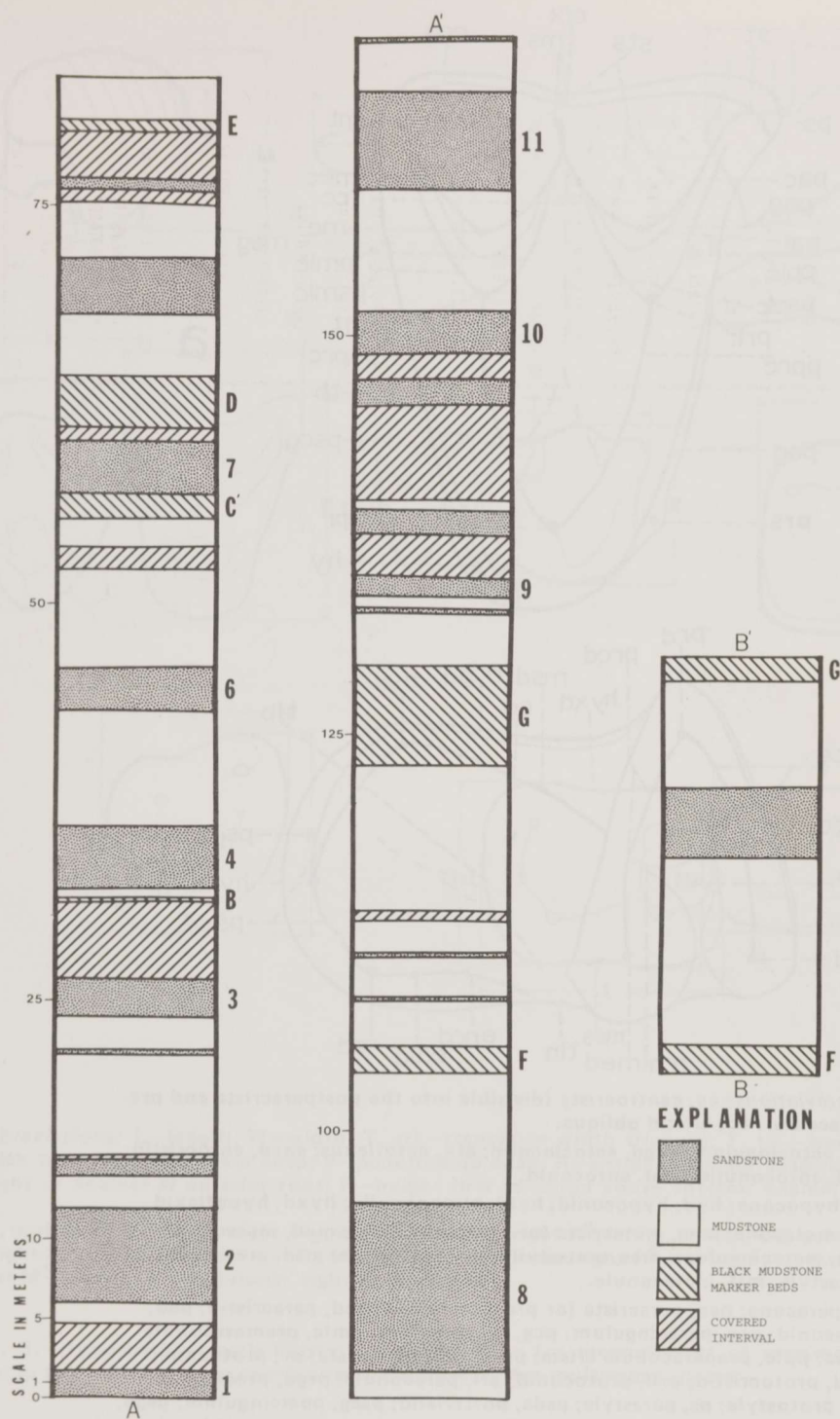
Fig. 3.—Simplified columnar sections along A-A' and B-B'. Location given
on figure 2. (A is the base of the formation and A' is the highest exposure.
B is the base of black mudstone F and B' is the highest exposure. Letters
and numbers are arbitrary designations.)

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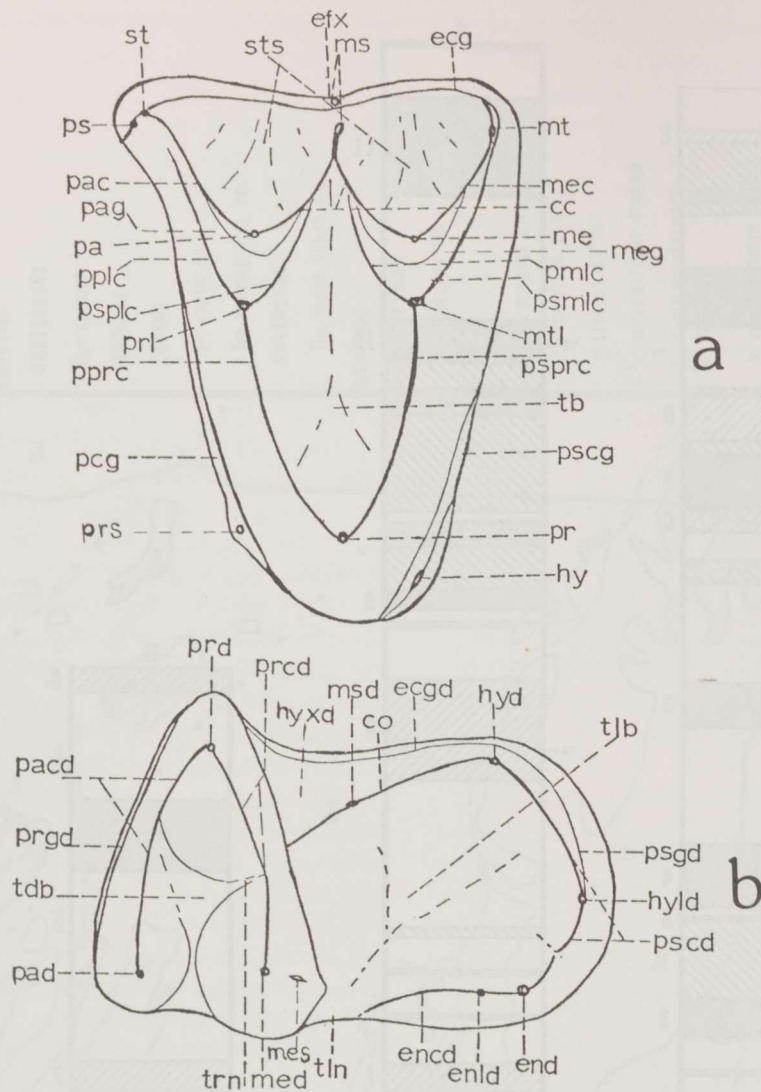
Abbreviations: cc, centrocrista (divisible into the postparacrista and pre-
metacrista); co, cristid obliqua.

ecg, ectocingulum; ecgd, ectocingulid; efx, ectoflexus; encd, entocristid;
enld, entoconulid; end, entoconid.

hy, hypocone; hyd, hypoconid; hyld, hypoconulid; hyxd, hypoflexid.

me, metacone; mec, metacrista (or postmetacrista); med, metaconid;
meg, metacingulum; mes, metastylid; ms. mesostyle; msd, mesoconid; mt,
metastyle; mtl, metaconule.

pa, paracone; pac, paracrista (or preparacrista); pacd, paracristid; pad,
paraconid; pag, paracingulum; pcg, precingulum; pmlc, premetaconule
crista; pplc, preparaconule crista; pprc, preprotocrista; pr, protocone;
prcd, protocristid; prd, protoconid; prl, paraconule; prgd, precingulid;
prs, protostyle; ps, parastyle; psdc, postcristid; pscg, postcingulum; psgd,
postcingulid; psmlc, postmetaconule crista; psplc, postparaconule crista;
psprc, postprotocrista.

st, stylocone; sts, stylar shelf.

tb, trigon basin; tdb, trigonid basin; tlb, talonid basin; tln, talonid notch;
trn, trigonid notch.

a. left upper molar. crown.

b. right lower molar. crown.

Fig. 4.—Hypothetical upper and lower molars illustrating the tooth
nomenclature used in this paper, modified from Szalay (1969, fig. 1).
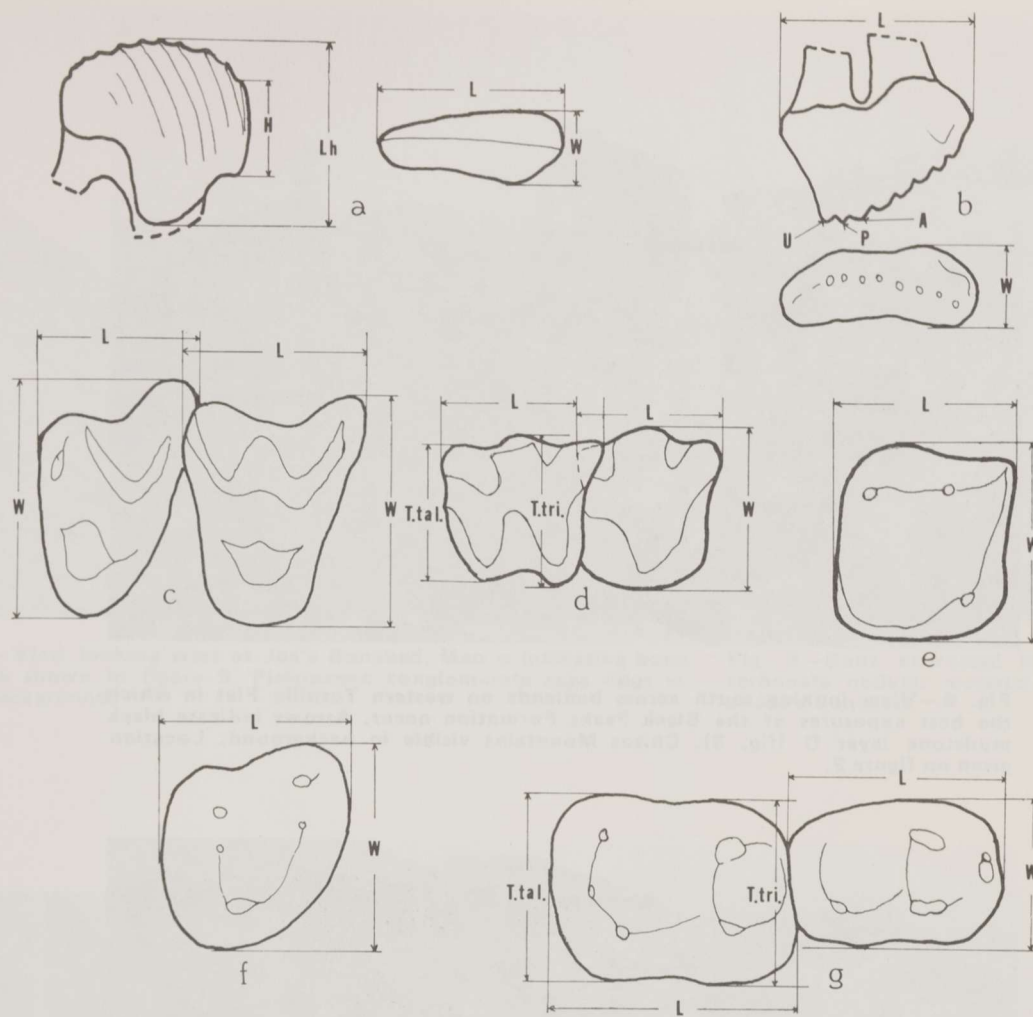
Abbreviations: L—length; W—width; T. tri.—transverse width trigonid; T. tal.—transverse width talonid; U—ultimate cusp; P—penultimate cusp; A—antepenultimate cusp; Lh—labial height of enamel at anterior root; H—height first serration above anterior enamel base.

a-b. multituberculate. a. right M_b, labial, crown; b. right P^4, labial, crown. c-d. pantodont. c. right M^2-M^3, crown; d. right P_4-M_1, crown. e. primate. right P^4, crown. f. arctocyonid. right M^3, crown. g. condylarth. right P_4-M_1, crown.

Fig. 5.—Hypothetical teeth illustrating orientations for measurement of mammal teeth used in this paper and the tooth nomenclature used for multituberculates.

Fig. 6.—View looking south across badlands on western Tornillo Flat in which the best exposures of the Black Peaks Formation occur. Arrows indicate black mudstone layer D (fig. 3). Chisos Mountains visible in background. Location given on figure 2.

Fig. 7.—View looking southeast. Sandstone bodies 2 and 3 in right foreground are approximately 6 meters thick. Rock in left foreground is part of a dike. Location given on figure 2.

Fig. 8.—View looking west at Joe's Bonebed. Man is indicating bone in place shown in figure 9. Pleistocene conglomerate caps ridge in right background.

Fig. 9.—Bone encrusted in calcium carbonate nodular material, in place at Joe's Bonebed.
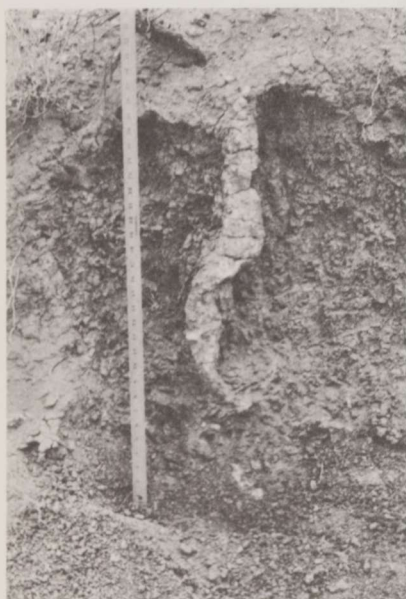
Fig. 10.—Microcrystalline calcium carbonate nodule, approximately 0.7 meter long, in place in gray mudstone. Location given on figure 2.

Fig. 11.—Large petrified log in sandstone 4.
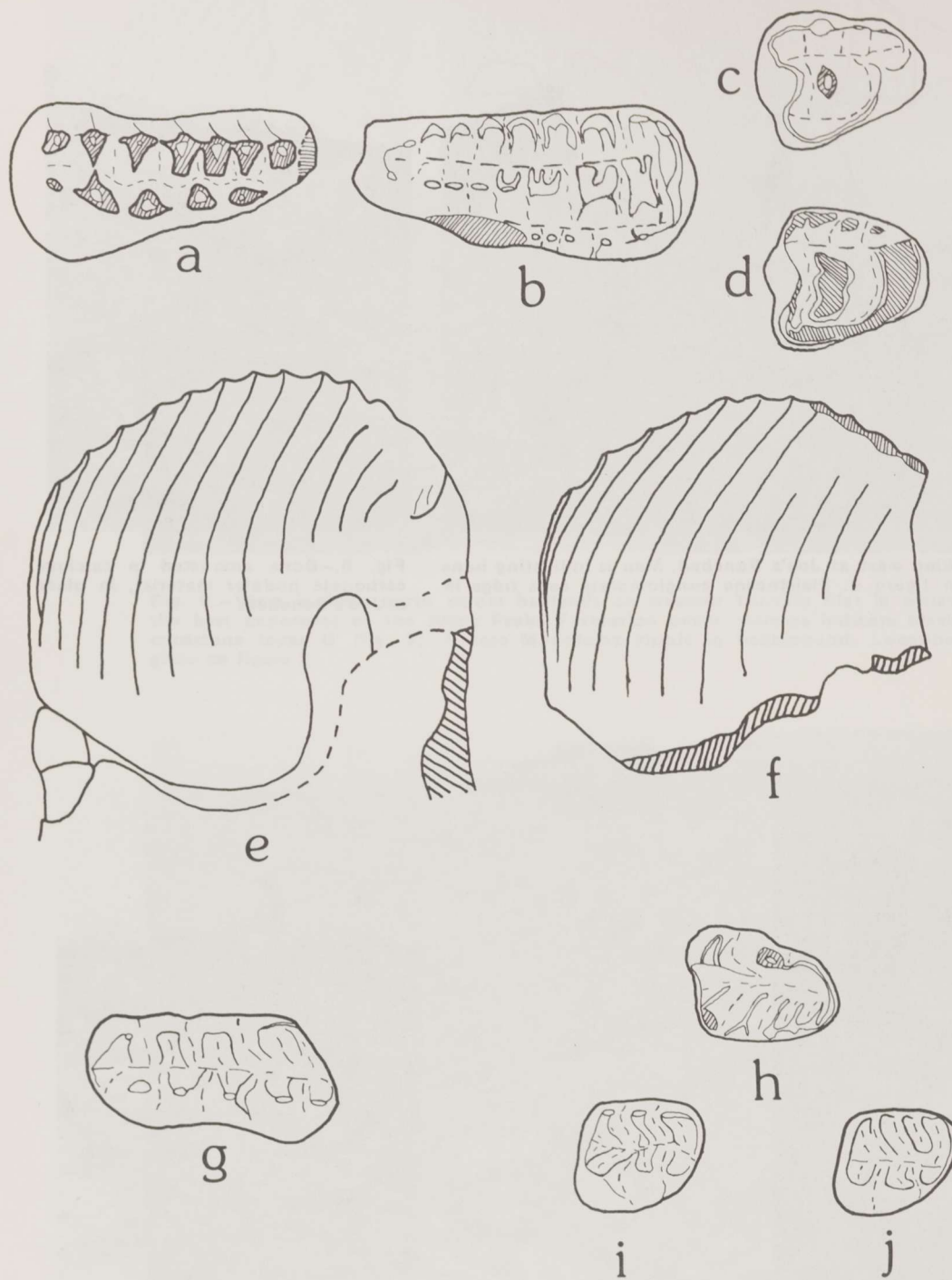
Fig. 12.—*Ptilodus mediaevus.* a. 41365-62, right P^4, crown; b. 41217-4, left M^1, crown; c. 41365-86, right M^2, crown; d. 41365-285, right M^2, crown; e. 40147-42, left mandible fragment with P_3-M_b, labial; f. 41365-445, left M_b, labial; g. 40147-47, left M_1, crown; h. 41365-181, left M_2, crown; i. 40147-46, right M_2, crown; j. 40147-45, right M_2, crown. X 10.
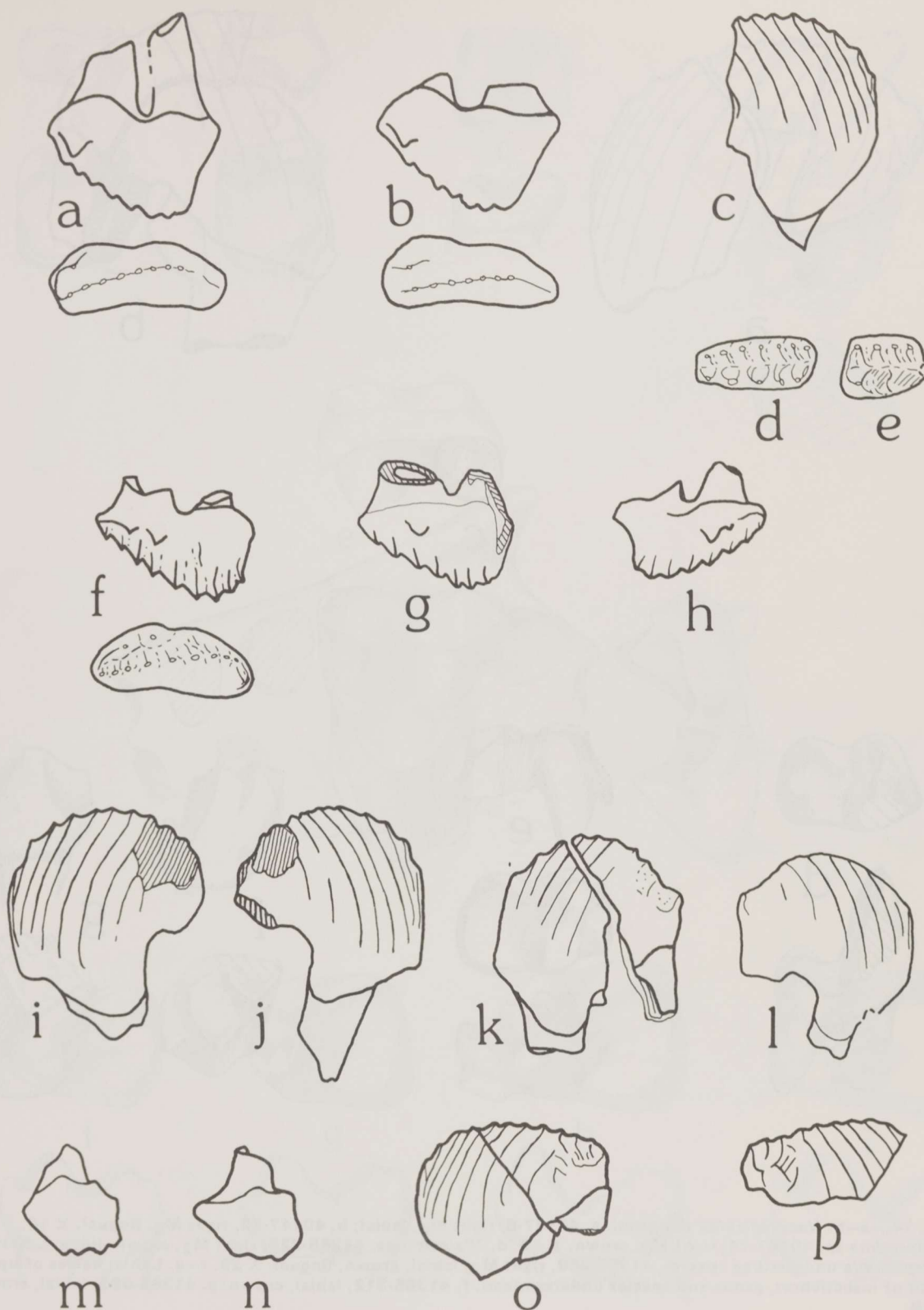
Fig. 13.—a—e. *Ectypodus musculus*. a. 41365-222, left P^4, labial, crown; b. 41365-195, left P^4, labial, crown; c. 41365-462, left M_b, lingual; d. ?41365-695, right M_1, crown; e. ?41365-528, right M_2, crown. X10. f—l. *Parectypodus sloani* n. sp. f. 40147-36, left P^4, labial, crown; g. 40147-41, left P^4, labial; h. 40147-37, right P^4, labial; i. 41365-113, left M_b, labial; j. 41365-184, right M_b, labial; k. 40147-35, right M_b, linguai; l. 40147-39, lingual half left M_b, lingual. X 10. m—p. *Mimetodon silberlingi*. m. 41365-641, right P^4, labial; n. 41365-53, right P^4, labial; o. 40147-34, left M_b, labial; p. 41365-311, posterior half right M_b, labial. X 10.
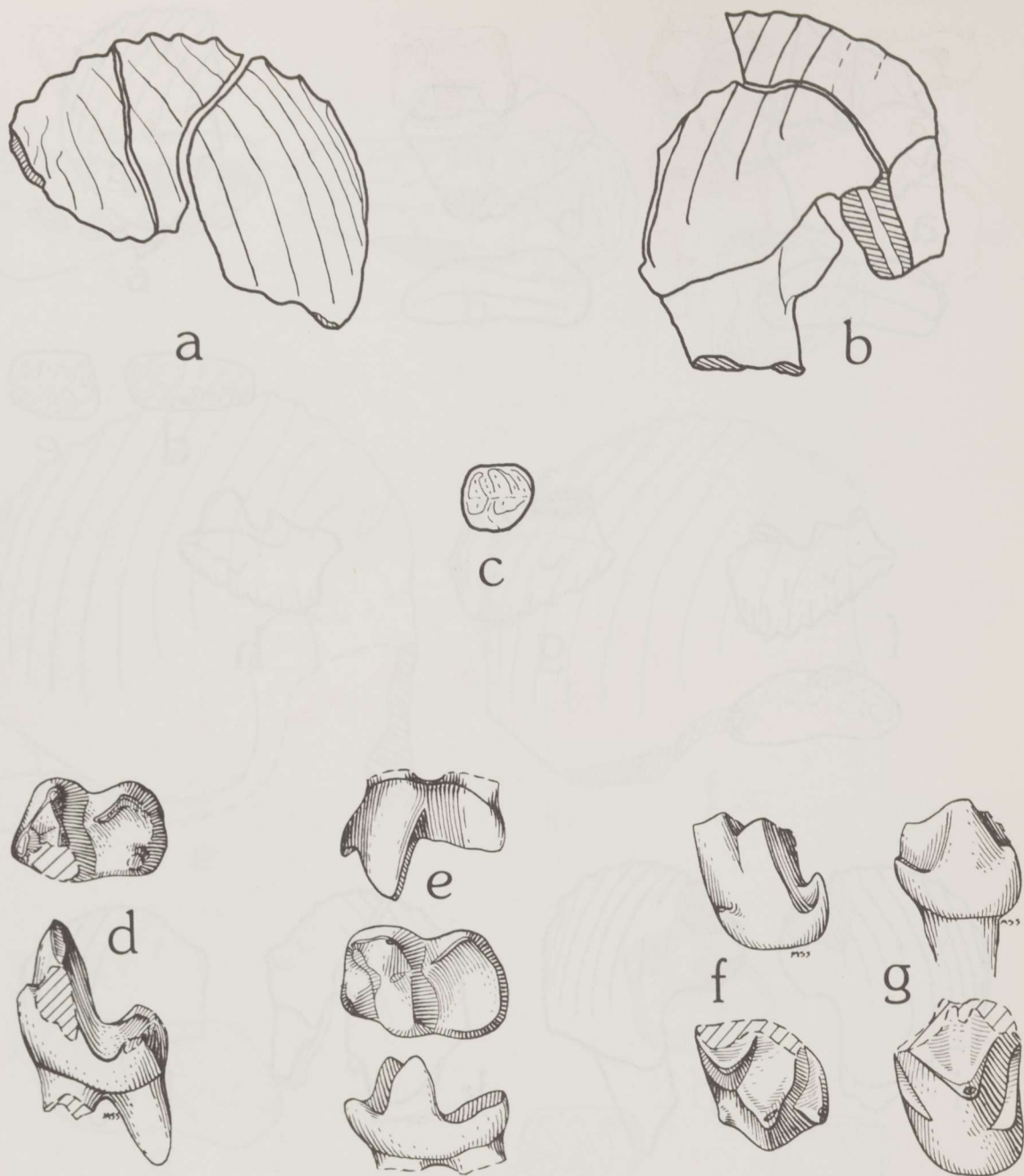
Fig. 14.—a—b. *Neoplagiaulax douglassi*. a. 40147-6, right M_b, labial; b. 40147-38, right M_b, lingual. X 10. c. *Mesodma* sp. 40147-74, right M_2, crown. X 10. d. *?Palaeictops*. 41365-326, right M_2, crown, lingual. X 10. e. *Jepsenella* undescribed species. 41365-269, right M_2, labial, crown, lingual. X 20. f—g. Labial halves of upper teeth of insectivores, genus and species undetermined. f. 41365-312, labial, crown; g. 41365-693, labial, crown. X 20.
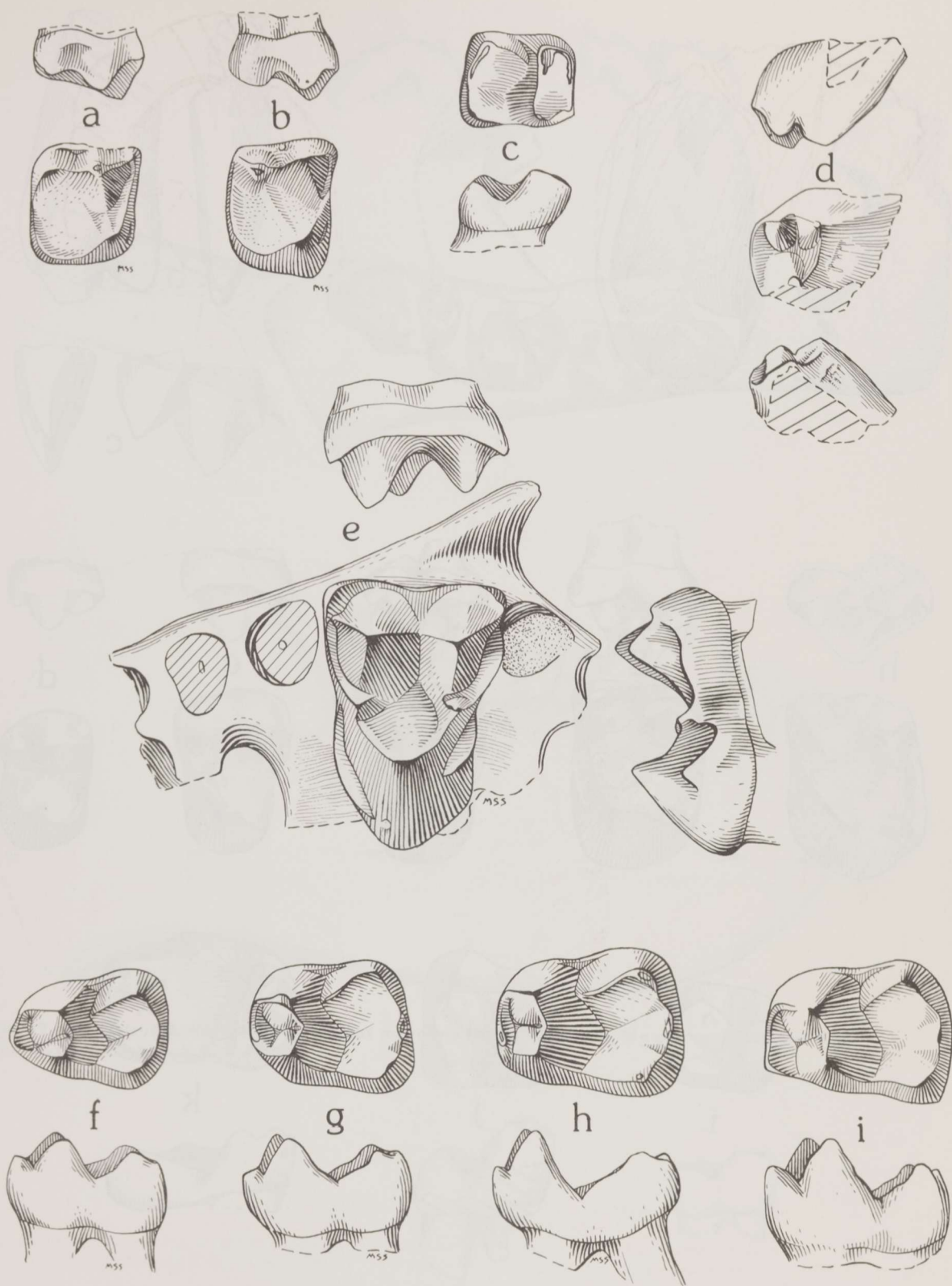
Fig. 15.—a–c. *Phenacolemur frugivorus*. a. 41365-682, right P^4, crown, labial; b. 41365-186, right M^2, crown, labial; c. 41365-19, left M_2, crown, lingual. X 10. d. *?Zanycteris*. 41365-145, left M_2 trigonid, lingual, crown, labial. X 10. e–i. *Navajovius kohlhaasae*. e. 40147-62, left M^2, labial, crown, posterior; f. 41365-340, left M_1, crown reversed, lingual reversed; g. 41365-500, right M_1, crown, lingual; h. 41365-636, right M_2, crown, lingual; i. 40537-127, right M_1, crown, lingual. X 20.
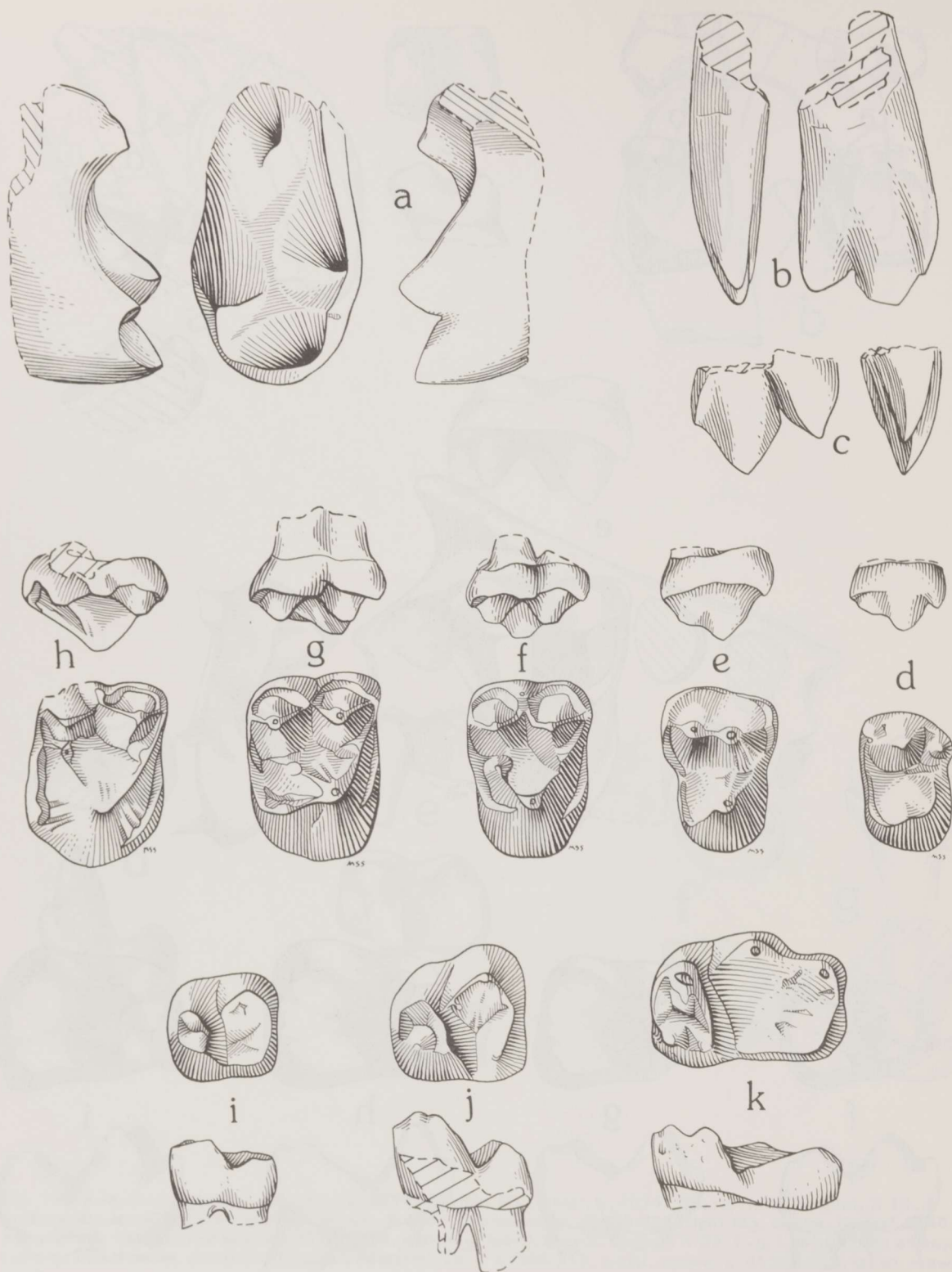
Fig. 16.—All from locality 41365. a. *Chiromyoides caesor*. -826, right upper I, medial, lingual, lateral. X 7. b—k. *Plesiadapis gidleyi*. b. -274, upper left I, lateral, lingual; c. -815, upper right I, lingual, lateral; d.-327, left P^3, labial reversed, crown reversed; e. -692, right P^4, labial, crown; f. -73, right M^1, labial, crown; g. -183, right M^2, labial, crown; h. -463, left M^3, labial reversed, crown reversed; i. -191, left ?M_1, crown reversed, lingual reversed; j. -399, left M_2, crown reversed, lingual reversed; k. -541, right M_3, crown, lingual. X 7.
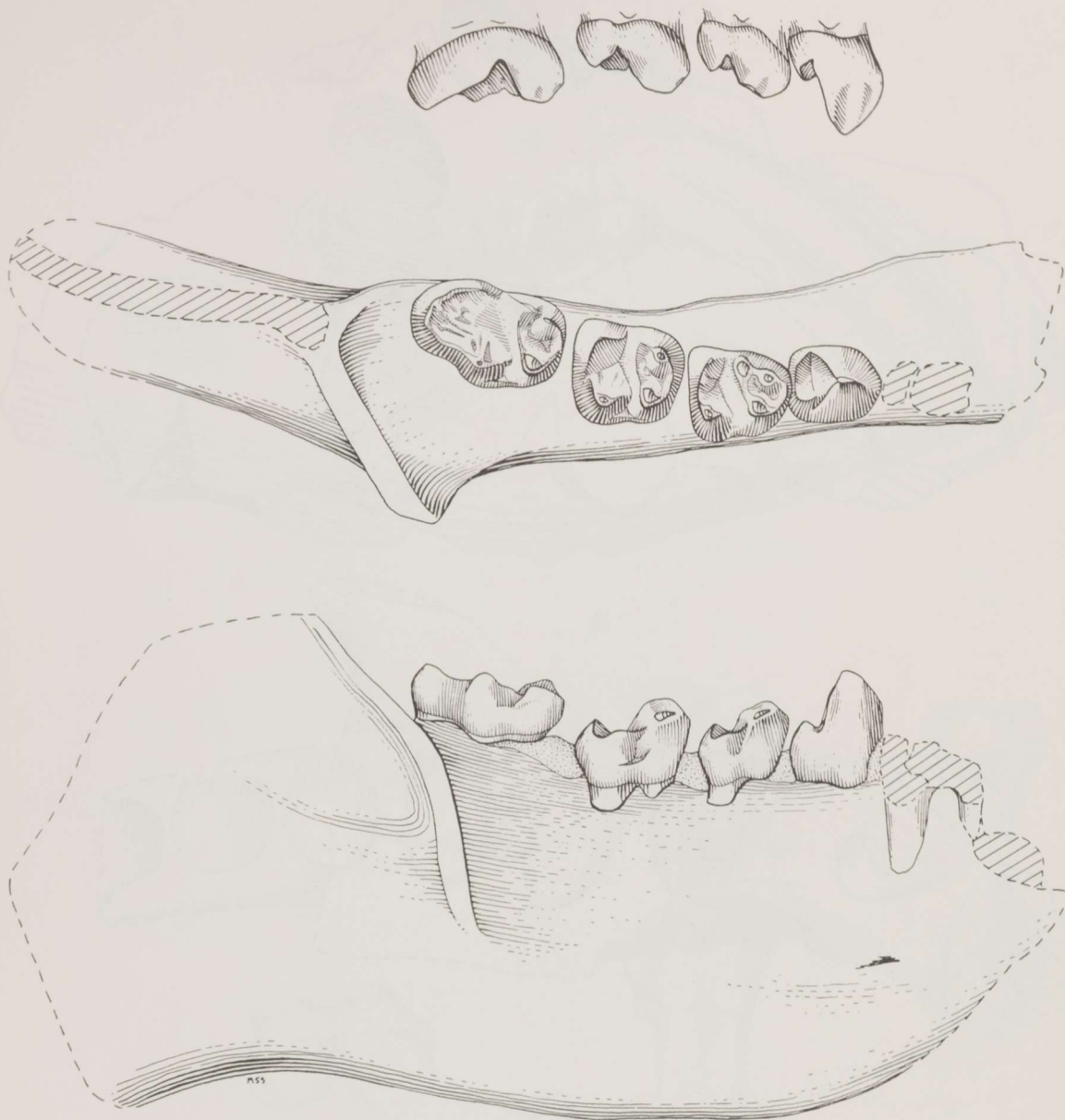
Fig. 17.—*Plesiadapis gidleyi.* 41366-77, right mandible fragment with P_4-M_3 and roots of I and P_3, lingual, crown, labial. X 5.
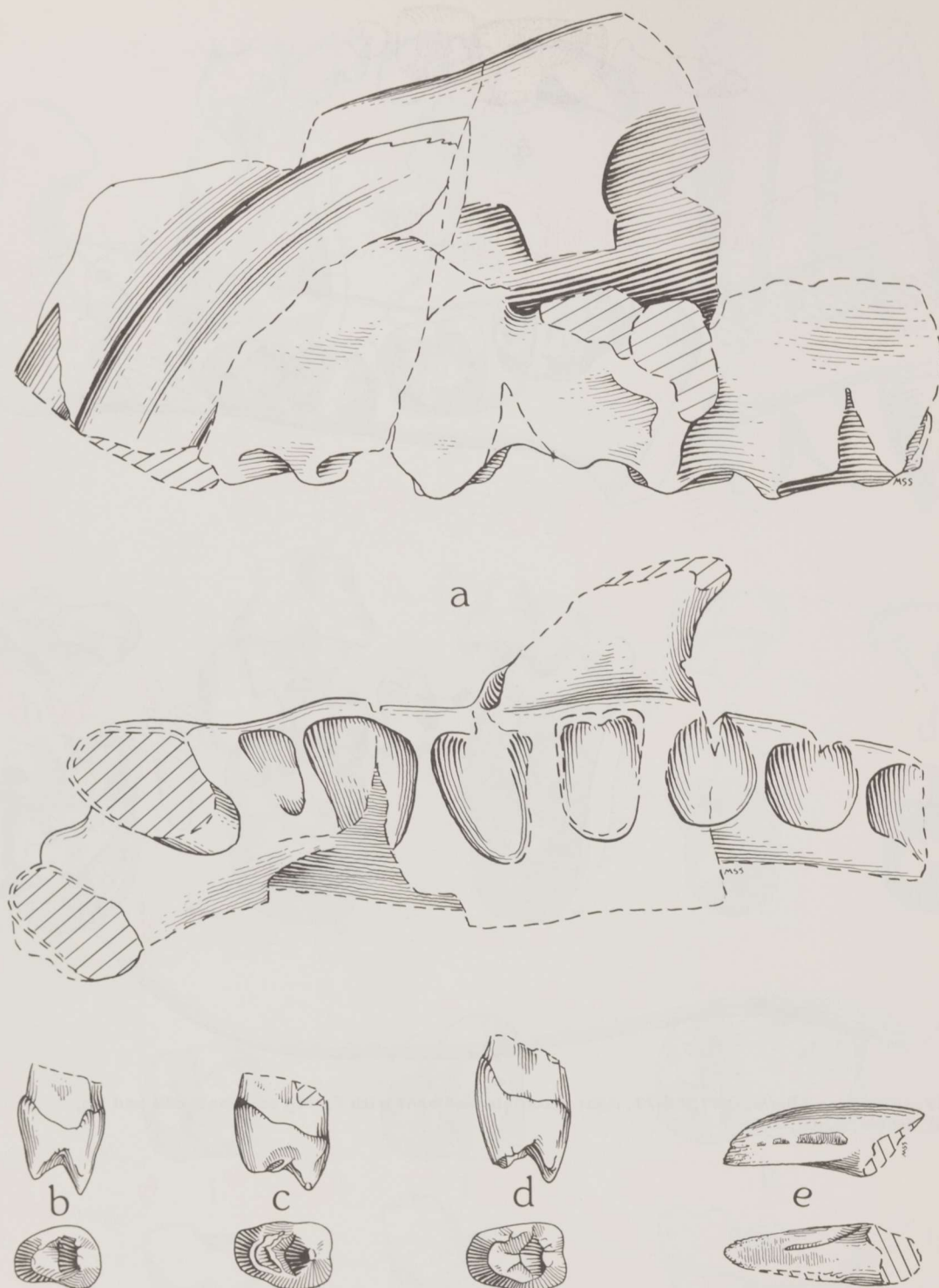
Fig. 18.—*Psittacotherium* or *Lampadophorus*. a. 41364-1, left maxilla showing canine root, labial, ventral; b. 40536-119, right P^2, posterior, crown; c. 40147-3, right P^3, posterior, crown; d. 40537-61, right M^1, posterior, crown; e. 40537-68, claw, lateral, ventral. X 1.
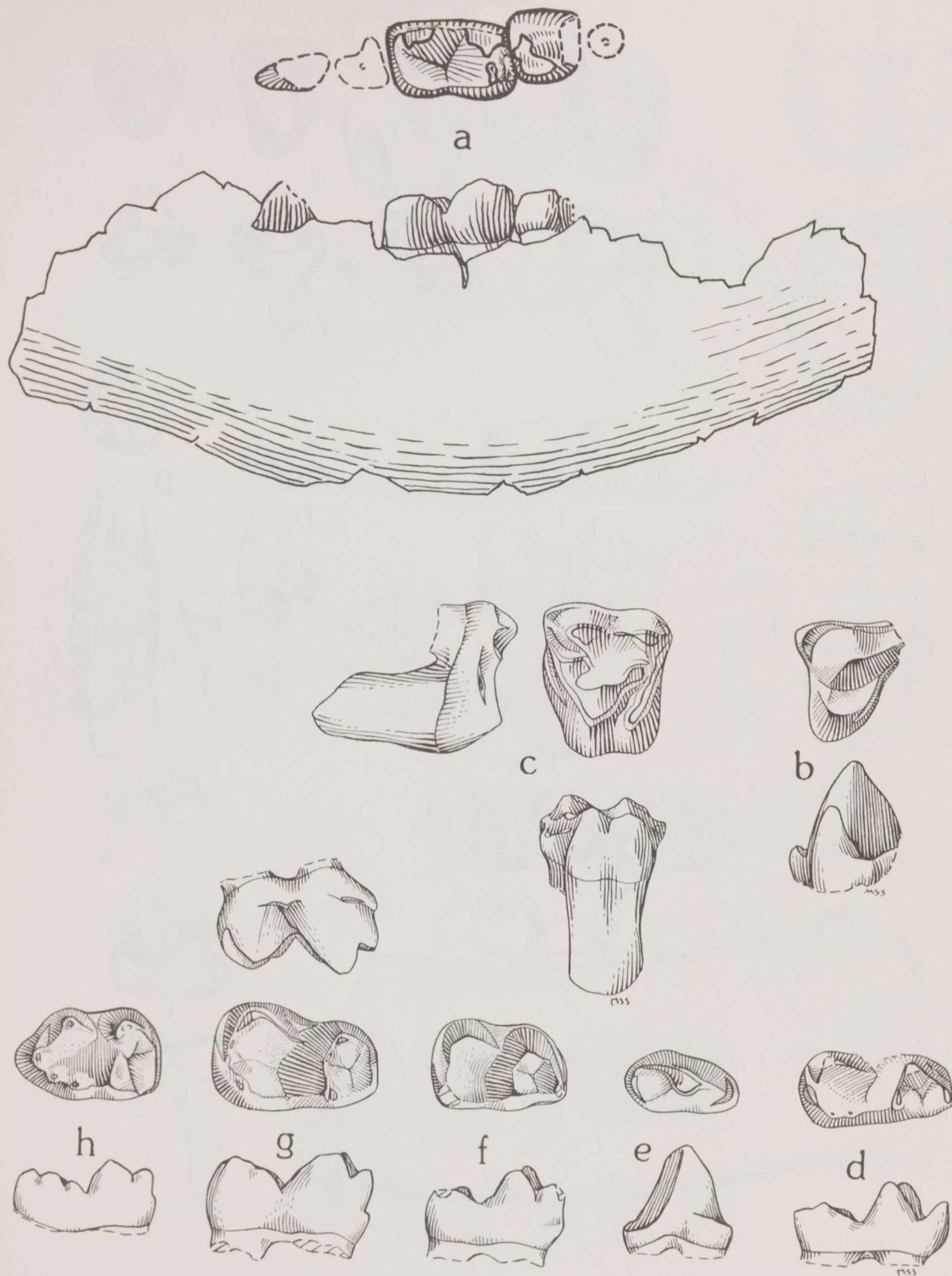
Fig. 19.—a. *?Deuterogonodon*. 40151-1, left mandible fragment with M_2 and talonid of M_1, crown, lingual. X 2. b–h. *Tricentes truncatus*. b. 41365-188, left P^4, lingual, crown; C. 41365-822, left M^1 or M^2, anterior, crown, lingual; d. ?41365-810, right dP_4, crown reversed, lingual reversed; e. 41365-32, right P_3, crown reversed, lingual reversed; f. 40537-88, left M_1, crown, lingual; g. 41365-616, left M_1, labial, crown, lingual; h. 41365-472, right M_3, crown reversed, lingual reversed. X 5.

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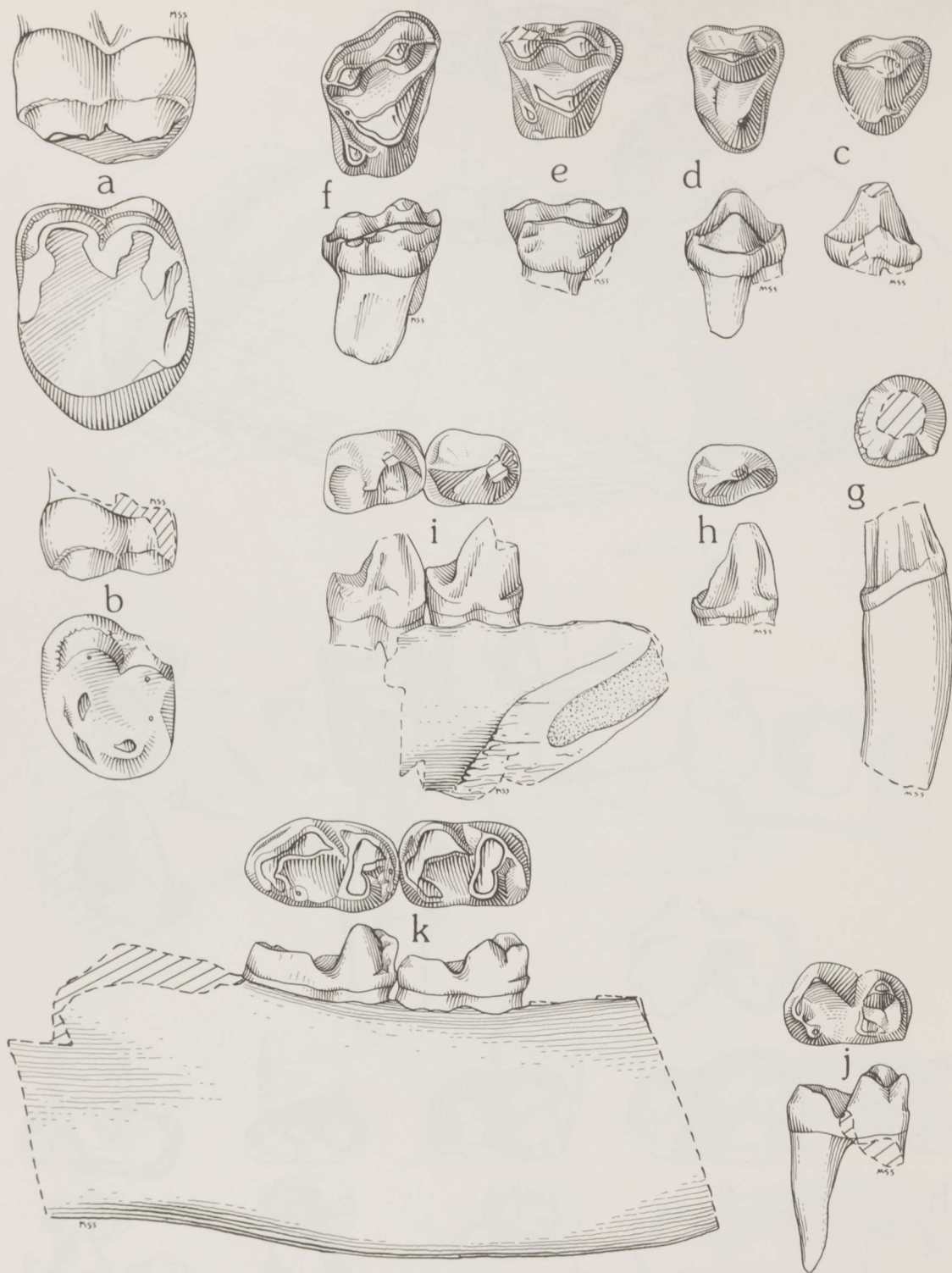
Fig. 20.—a—b. *Arctocyon* cf. *A. ferox*. a. 41366-81, left M^2, labial, crown; b. 41366-65, left M^3, labial, crown. X 2. c—k. Undescribed genus and species of arctocyonid. c. 41365-168, right P^3, crown, lingual; d. 41365-389, left P^4, crown reversed, lingual reversed; e. 41365-764, left M^1, crown reversed, lingual reversed; f. 41365-801, right M^2, crown, lingual; g. 41366-30, left lower canine, crown, labial; h. 41365-567, left P_2, crown, lingual; i. 41365-346, right mandible fragment with P_3-P_4, crown reversed, lingual reversed; j. 41365-531, right M_1, crown reversed, lingual reversed; k. 41376-2, left mandible fragment with M_2-M_3, crown, lingual. X 3.
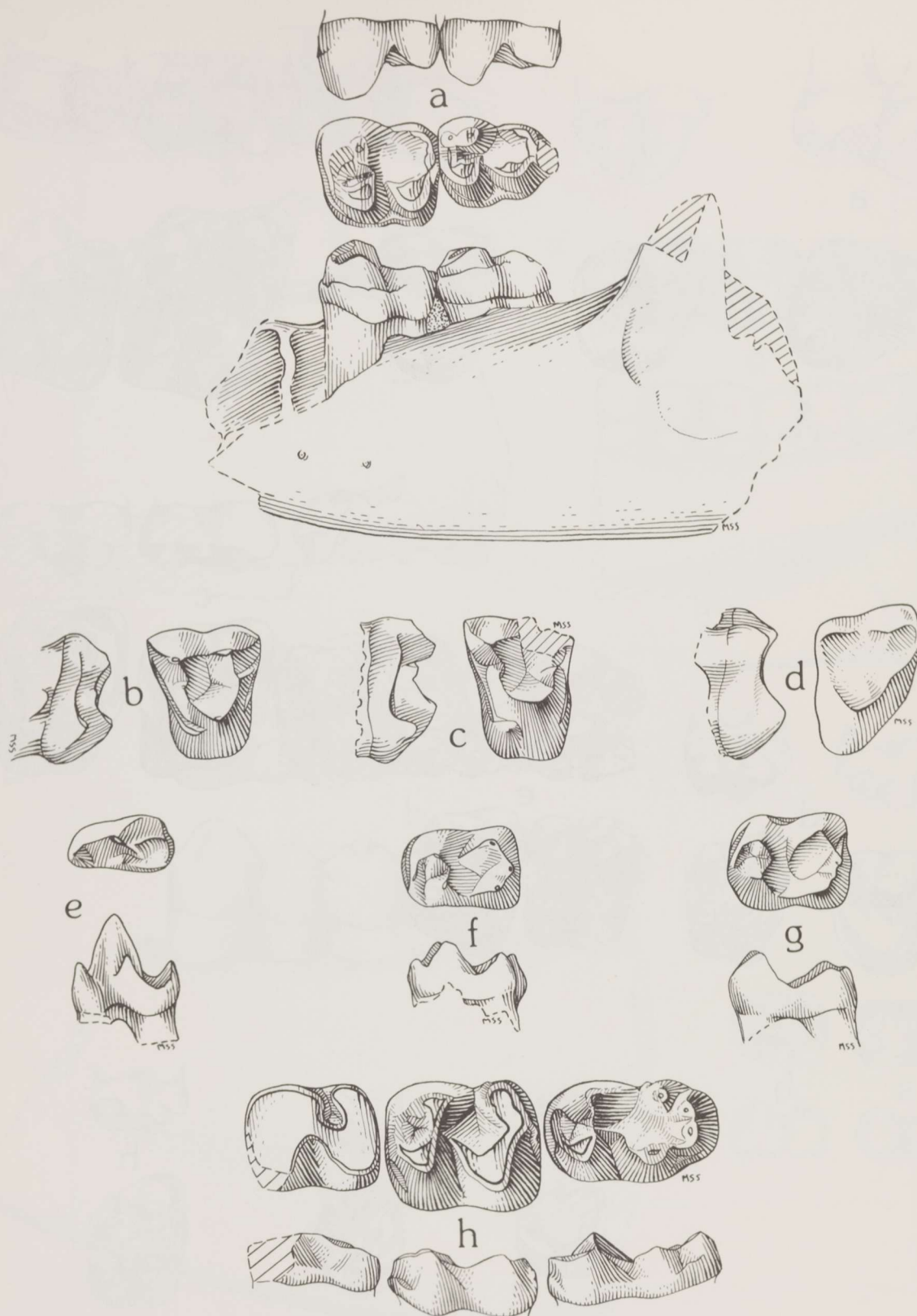
Fig. 21.—a. *Promioclaenus acolytus*. 41274-10, left mandible fragment with M_2-M_3, lingual, crown, labial. X 5. b–g. *Haplaletes disceptatrix*. b. 41365-351, right M^1, crown, posterior; c. 41365-358, right M^2, crown, posterior; d. 41365-849, right M^3, crown, posterior; e. 41365-457, right P_4, crown, lingual. f. 41365-361, right M_1, crown, lingual; g. 41365-193, left M_2, crown reversed, lingual reversed. X 7. h. *Protoselene opisthacus*. 40537-129, left M_1-M_3, crown, labial. X 5.

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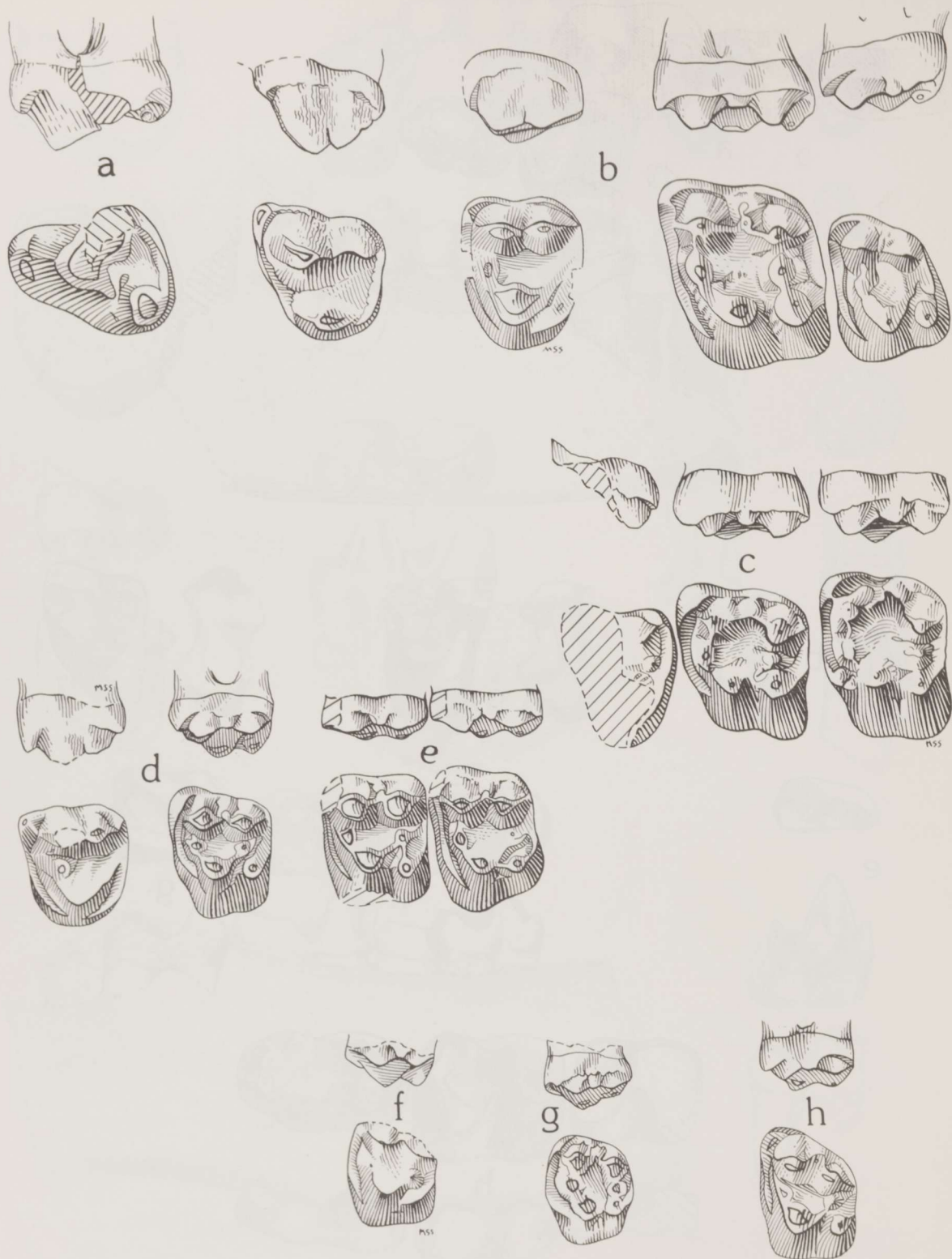
Fig. 22.—a—c. *Phenacodus grangeri*. a. 40148-23, right dP^3, labial reversed, crown reversed; b. 41366-11, left P^3, labial, crown, right P^4, right M^2-M^3, labial reversed, crown reversed; c. 41366-60, left P^4-M^2, labial, crown. X 2. d—e. *Phenacodus* cf. *P. matthewi*. d. 40147-19, left P^4, left M^2, labial, crown; e. 41366-27, left M^1-M^2, labial, crown. X 2. f—h. *Ectocion* cf. *E. montanensis*. f. 41365-784, right M^1, labial reversed, crown reversed; g. 41365-825, left M^1, labial, crown; h. 40536-167, right M^2, labial reversed, crown reversed. X 2.
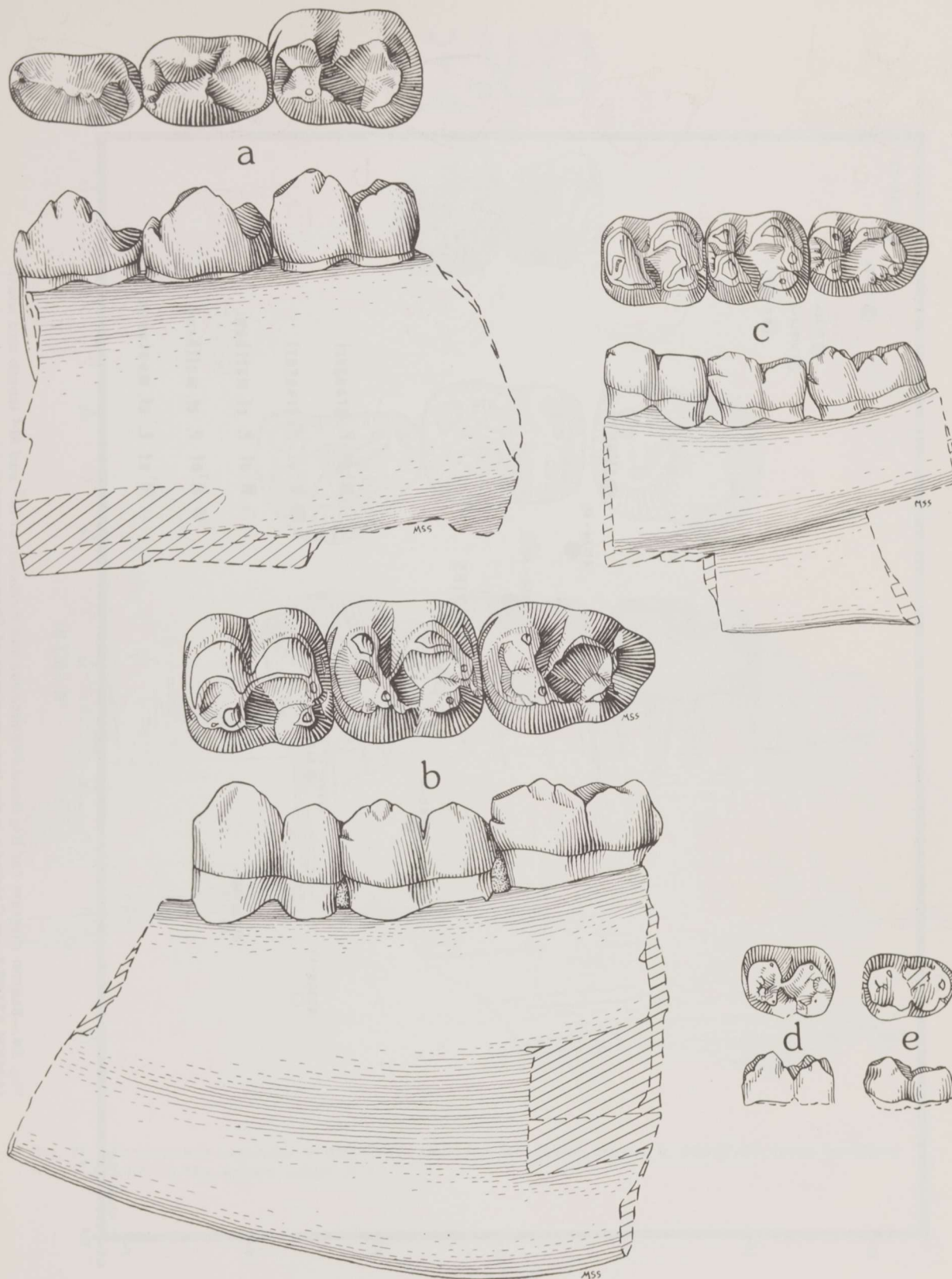
Fig. 23.—a—b. *Phenacodus grangeri*. a. 41366-29, right mandible fragment with P_3-M_1, crown, lingual; b. 41366-37, right mandible fragment with M_1-M_3, crown, lingual. X 2. c. *Phenacodus* cf. *P. matthewi*. 40148-6, right mandible fragment with M_1-M_3, crown, lingual. X 2. d—e. *Ectocion* cf. *E. montanensis*. d. 41365-16, left M_1 or M_2, crown reversed, lingual reversed; e. 41365-307, right M_3, crown, lingual. X 2.

WIDTH

LENGTH

40148-23
40148-10
41366-36
41366-11
41368-1
AMNH17185
41366-60
41366-69
41366-60
AMNH17185
40148-4
41366-27
41366-27
40148-19
40536-167
41365-825

○ M¹ of P. grangeri
● M² of P. grangeri
○ M¹ of P. cf. matthewi
● M² of P. cf. matthewi
○ M¹ of E. cf. montanensis

17 16 15 14 13 12 11 10 9 8,4

13 12 11 10 9 8 7 6.8
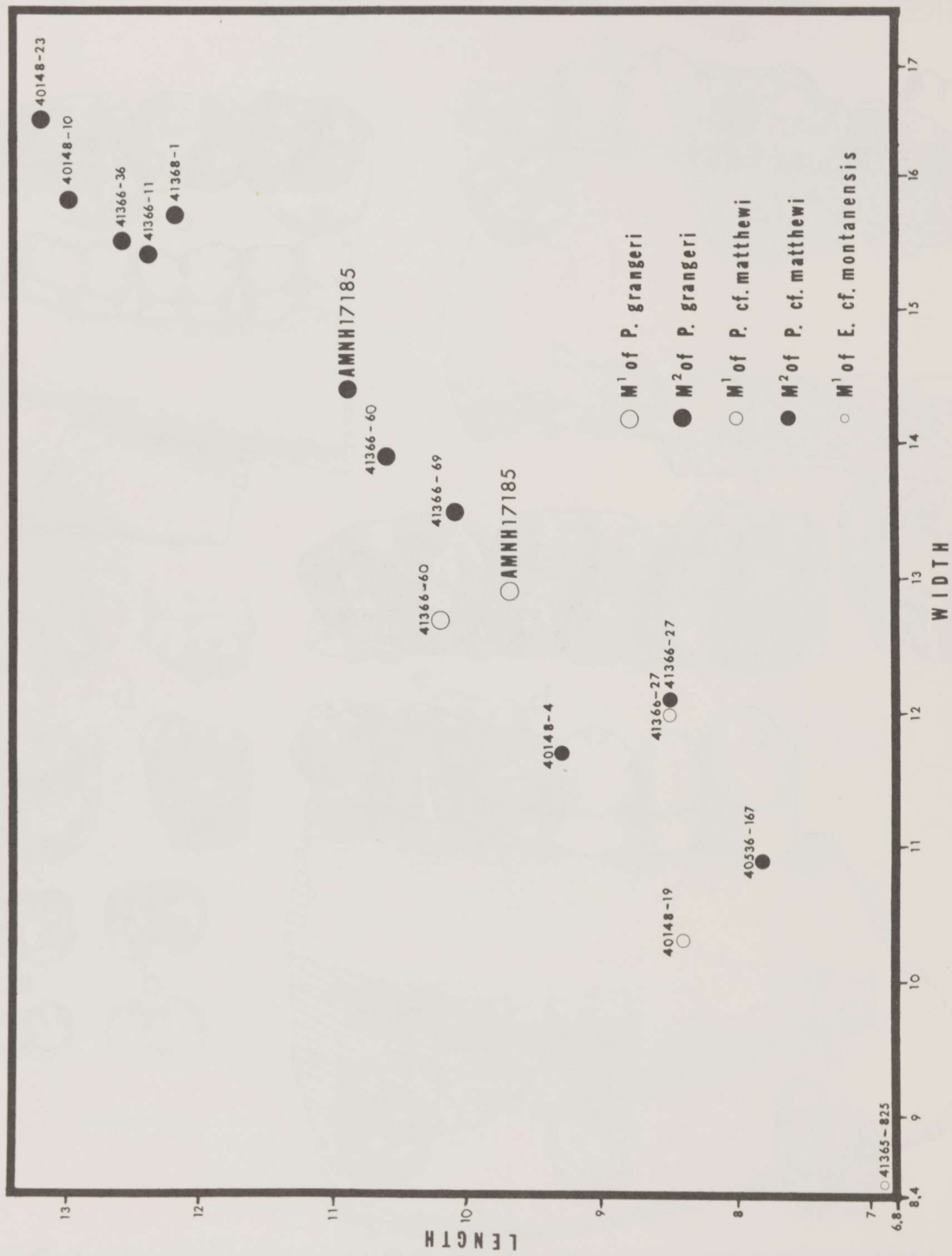
Fig. 24.—Scatter diagram for Big Bend *Phenacodus* and *Ectocion* of M¹ and M² length and width. (AMNH 17185 from Colorado is the type specimen of *Phenacodus grangeri*.)
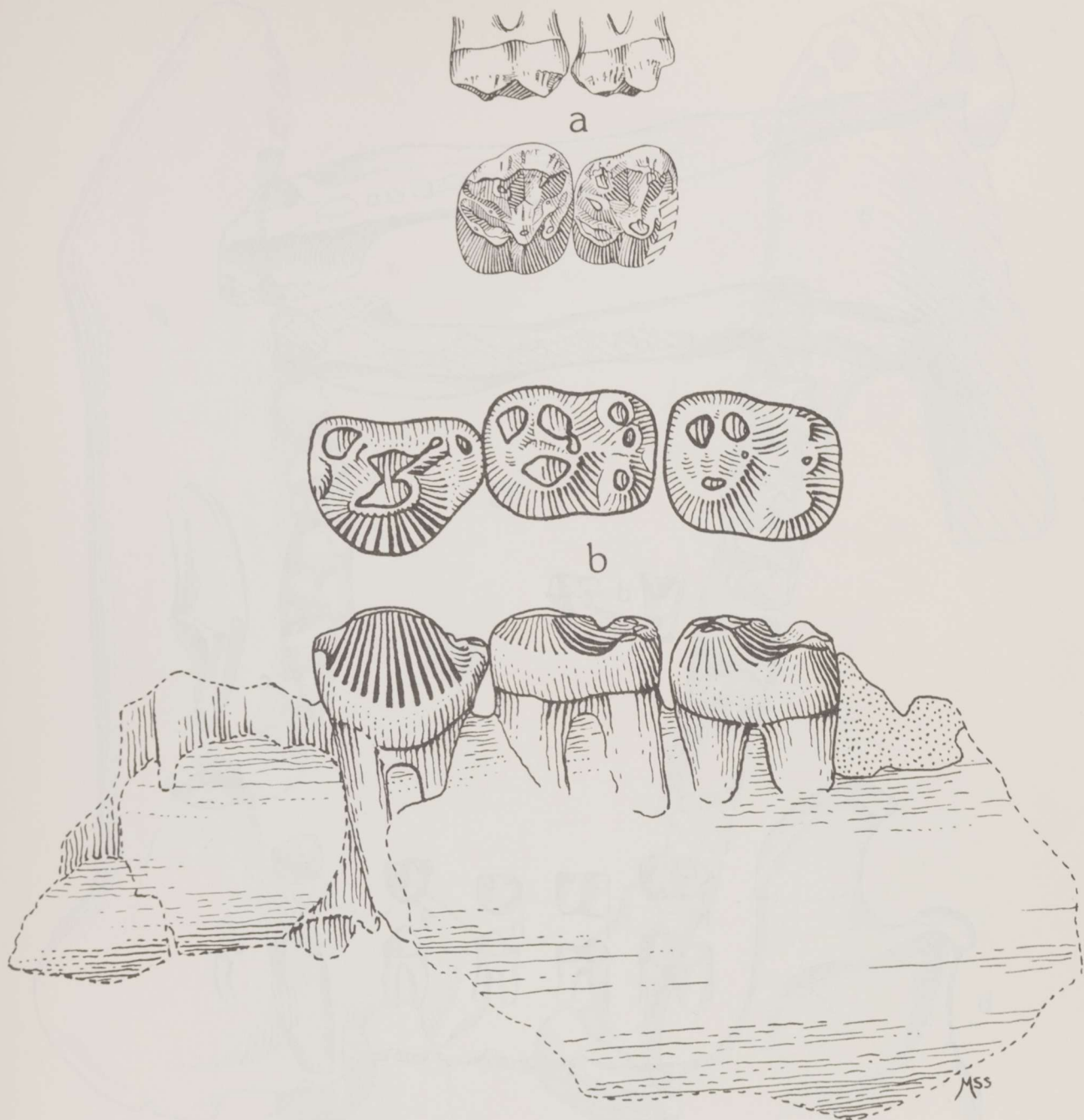
Fig. 25.—*Periptychus superstes.* a. 40147-17, right M^1-M^2, labial, crown; b. 40537-59, right mandible fragment with P_4-M_2, crown, labial. X 2.
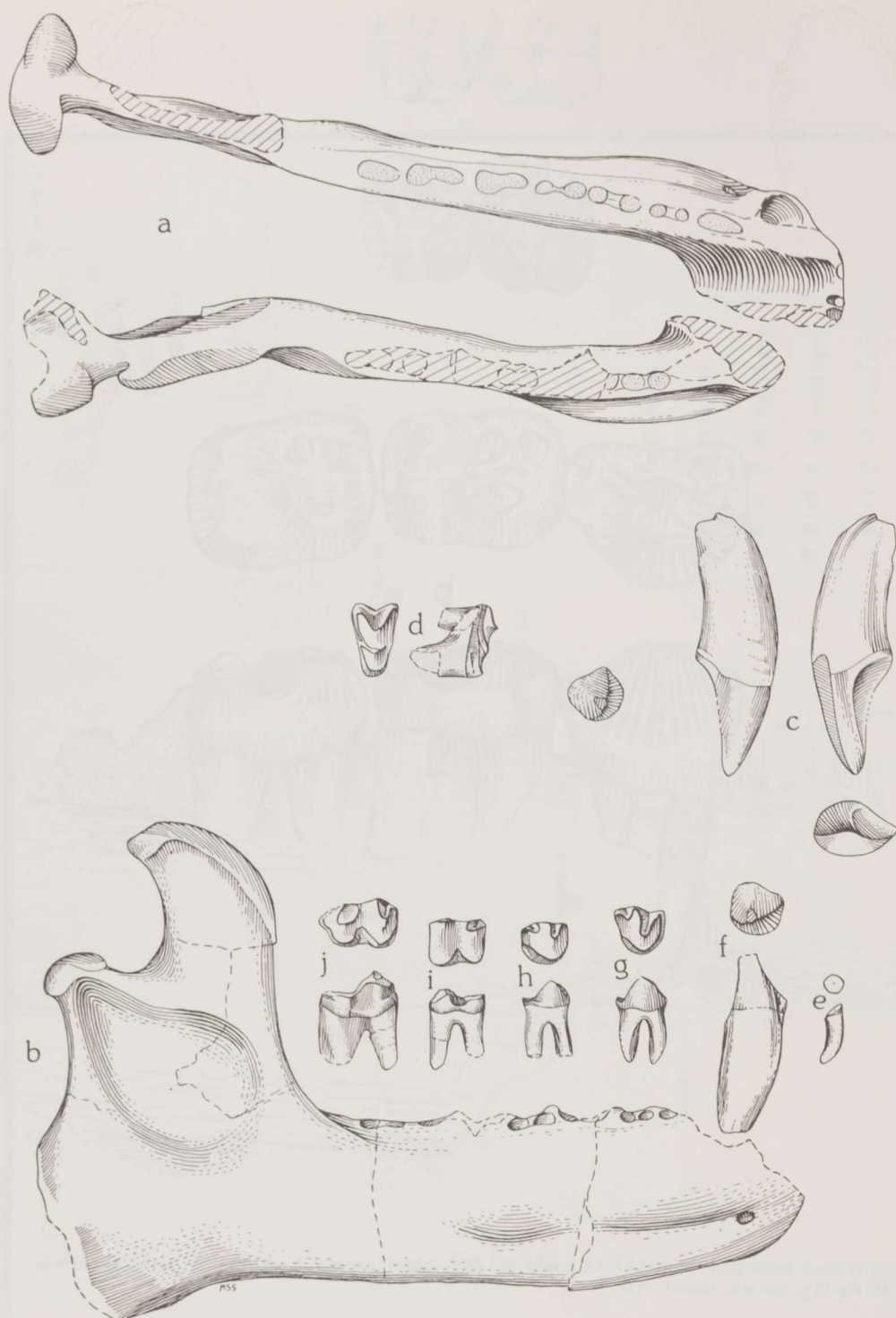
Fig. 26.—*Caenolambda* sp., all 41377-1. a. mandibles, dorsal; b. right mandible, lateral; c. right upper canine, lingual, labial, crown; d. left upper premolar, anterior, crown; e. incisor, crown, lateral; f. left lower canine, crown reversed, labial reversed; g. left P_2, crown reversed, labial reversed; h. right P_4, crown, labial; i. left M_1, crown reversed, labial reversed; j. right M_3, crown, labial. X .7.
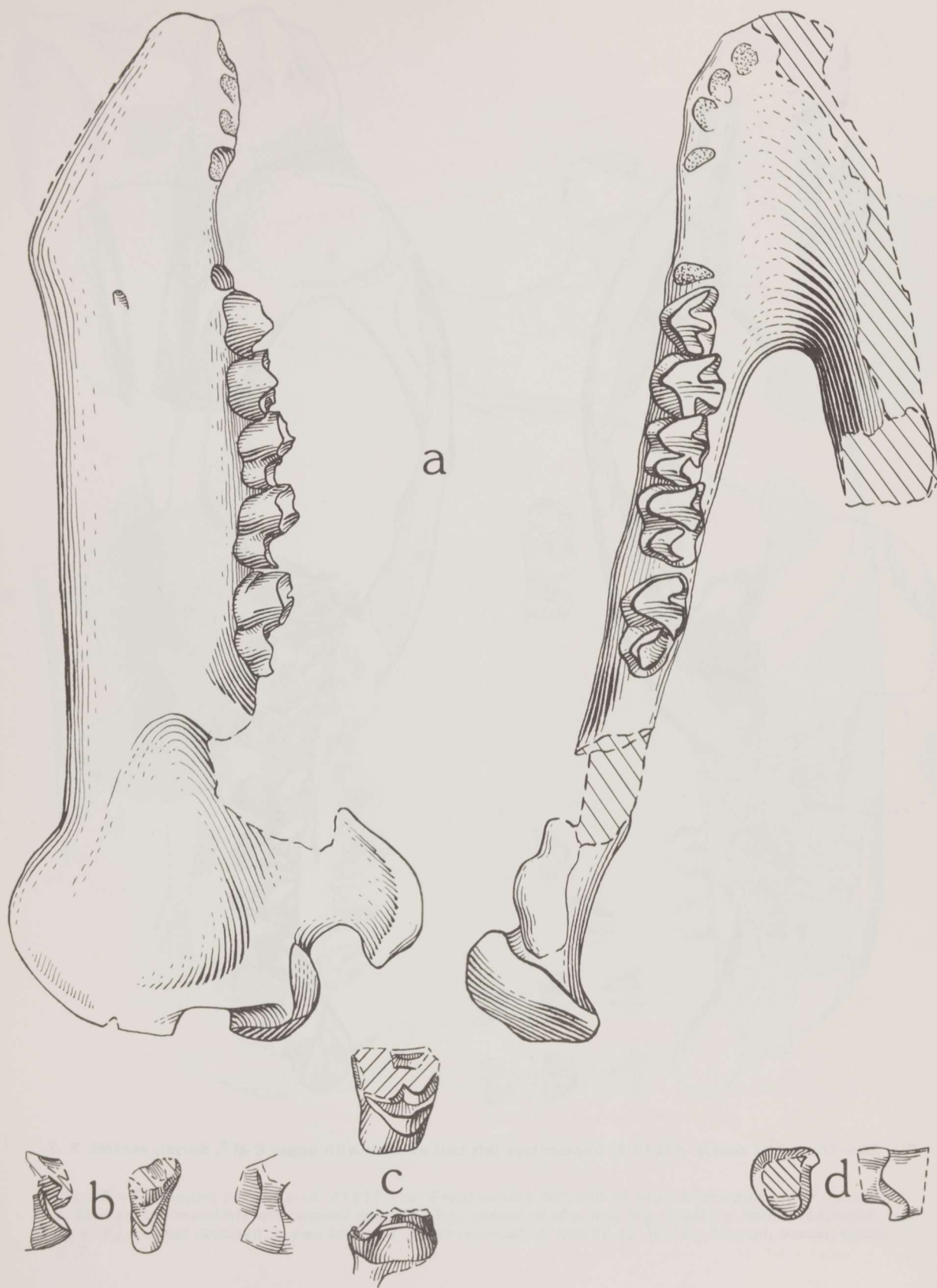
Fig. 27.—a—c. *Barylambda jackwilsoni* n. sp. a. 40537-83, left mandible with P_3-M_3, lateral, crown; b. 40536-156, left ?P^3, anterior, crown, posterior; c. 40536-173, right M^1, crown, lingual. X .7. d. *Barylambda* sp. 41221-11, left P_4, crown, labial. X .7.
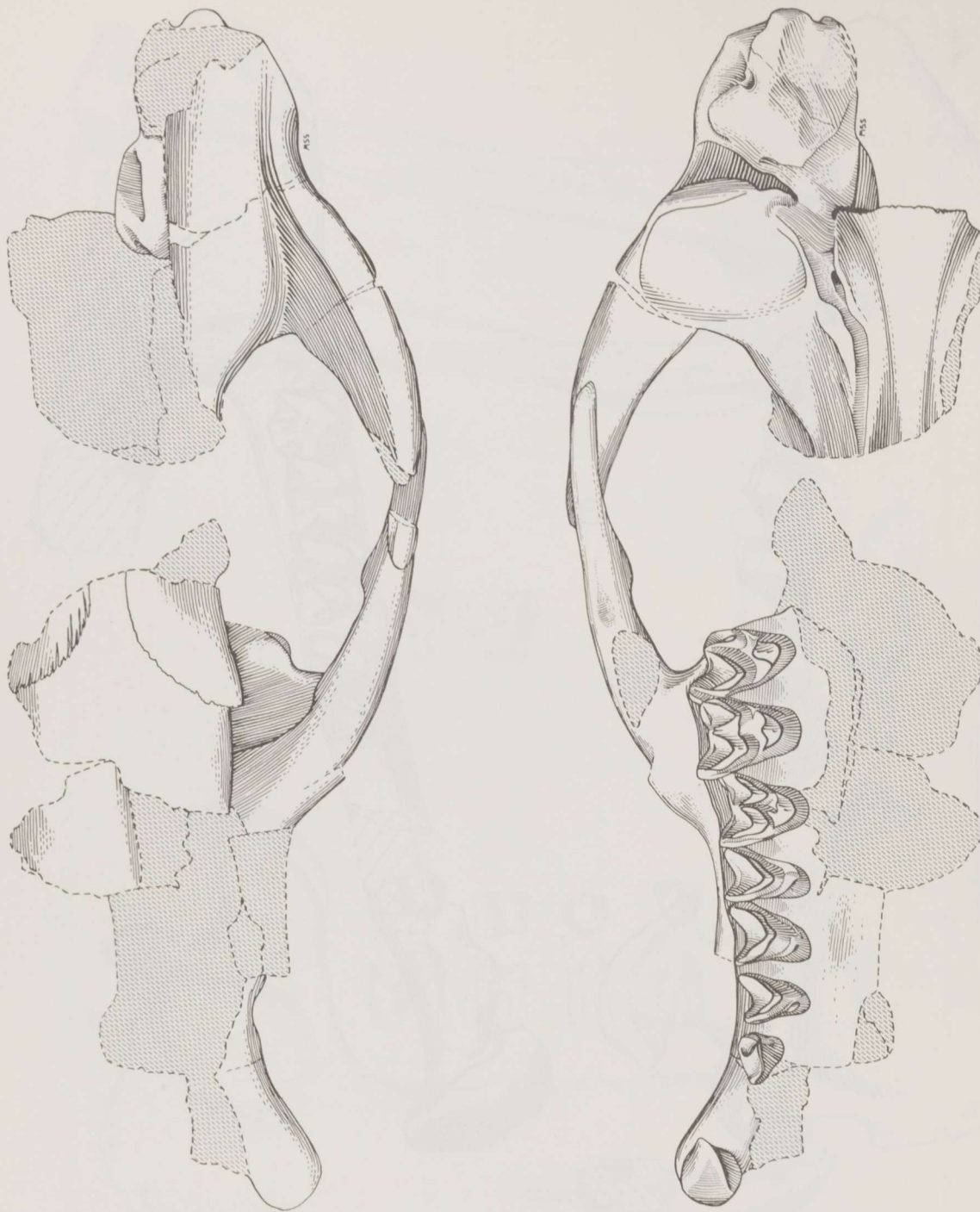
Fig. 28.—*Titanoides zeuxis*. 41217-1, fragmentary left half of skull with upper C-M^3, dorsal, ventral. X .7.

Fig. 29.—*Titanoides zeuxis.* a—b. 41217-1. a. Fragmentary left half of skull with upper C-M^3, lateral; b. Broken left mandible with canine root, P$_1$, P$_2$, talonid of M$_2$, and M$_3$, lateral; c. 40535-84, right P$_3$ or P$_4$, lingual reversed, crown reversed, labial reversed; d. 40537-73, left P$_3$, lingual, crown, labial. X .7.
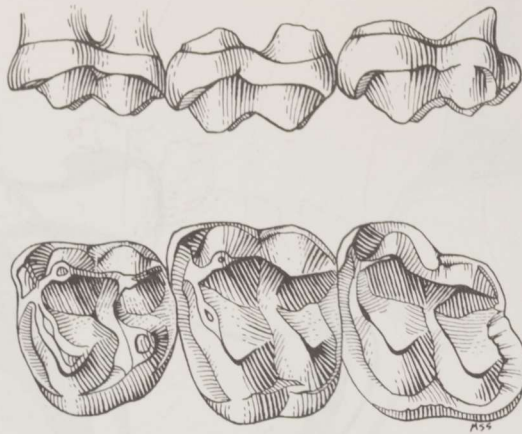
Fig. 30.—*Hyracotherium angustidens*. 41221-8, left M^1-M^3, labial, crown. X 3.

Fig. 31.—View looking northwest at point bar deposits associated with sandstone body 6 which can be seen in the right background. Maximum thickness of sandstone body 6 is ten meters. Location given on figure 2.
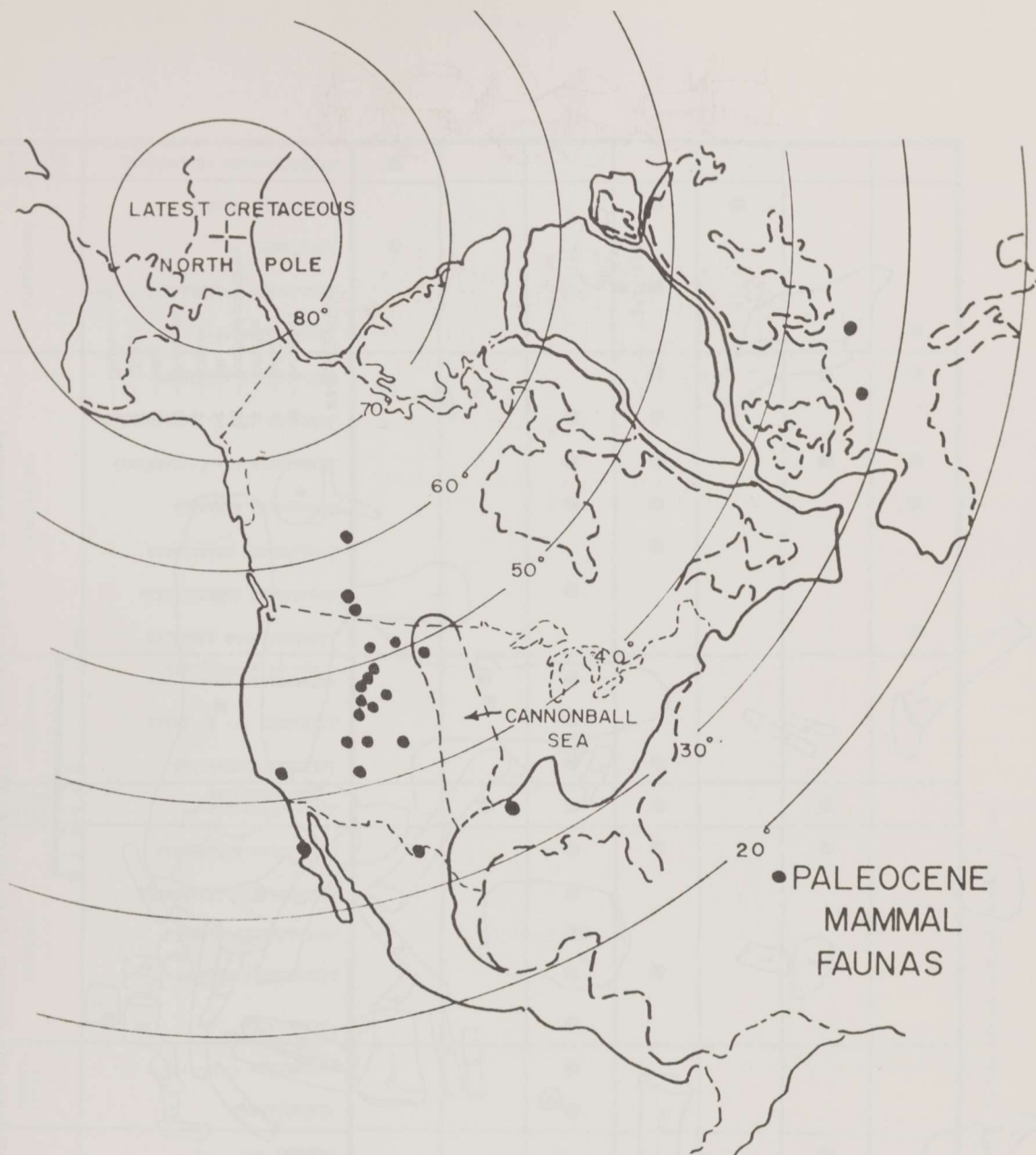
Fig. 32.—Palinspastic map of the geographic distribution of known mammal localities during the Paleocene, from Sloan (1969, fig. 4).

Map labels: LATEST CRETACEOUS NORTH POLE, 80°, 70°, 60°, 50°, 40°, 30°, 20°, CANNONBALL SEA, ●PALEOCENE MAMMAL FAUNAS
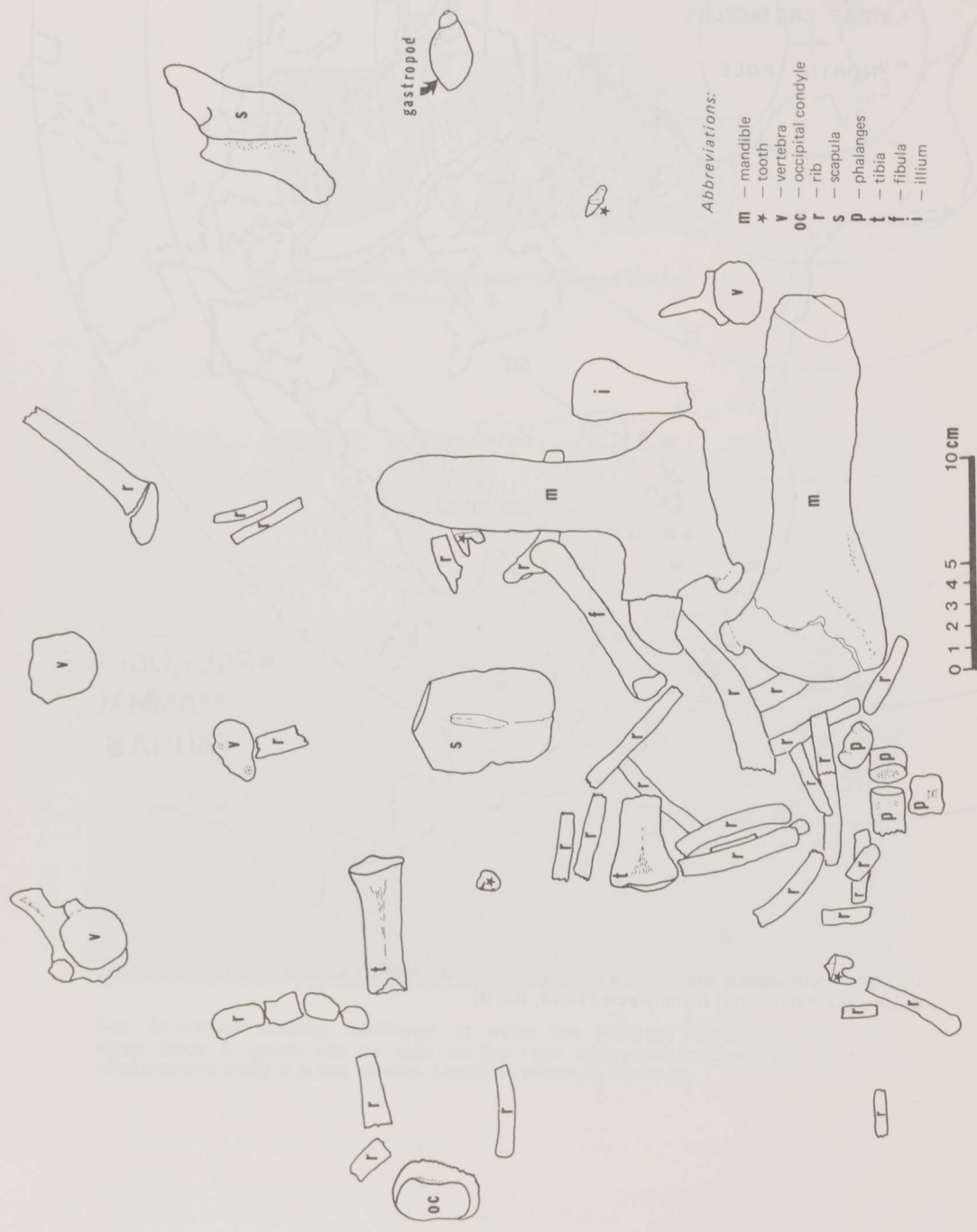
Abbreviations:

m — mandible
* — tooth
v — vertebra
oc — occipital condyle
r — rib
s — scapula
p — phalanges
t — tibia
f — fibula
i — illium

Fig. 33.—Orientation diagram of specimen 41377-1, *Caenolambda* sp., as preserved in gray mudstone.

Fig. 34.—Distribution of mammals within the Black Peaks Formation.

Order	Taxon	137 m (450') 41221	105 m (345') 41364, 41376	79-85 m (260'-280') 41365, 41366	49-59 m (160'-195') 40535, 40536, 40537, 40148, 40642, 41368, 41367, 41273	43 m (140') 41217	43 m (140') 40147*	23 m (75') 41377, 41274
PERISSODACTYLA	Hyracotherium angustidens	●						
PANTODONTA	Titanoides zeuxis				●	●		
PANTODONTA	Barylambda sp.	●						
PANTODONTA	Barylambda jackwilsoni n. sp.				●			
PANTODONTA	Caenolambda sp.							●
CONDYLARTHRA	Periptychus superstes				●		●	●
CONDYLARTHRA	Ectocion cf. E. montanensis			●	●			
CONDYLARTHRA	Phenacodus cf. P. matthewi			●	●		●	●
CONDYLARTHRA	Phenacodus grangeri			●	●			●
CONDYLARTHRA	Protoselene opisthacus				●			
CONDYLARTHRA	Haplaletes disceptatrix			●				
CONDYLARTHRA	Promioclaenus acolytus							●
CARNIVORA	undescribed genus and sp. of arctocyonid		●	●				
CARNIVORA	Arctocyon cf. A. ferox			●				
CARNIVORA	Tricentes truncatus			●	●			
TAENIODONTA	Psittacotherium or Lampadophorus		●	●	●		●	
PRIMATES	Navajovius kohlhaasae			●	●		●	
PRIMATES	Phenacolemur fruigivorus			●				
PRIMATES	Chiromyoides caesor			●				
PRIMATES	Plesiadapis fidleyi			●	●			
PRIMATES	?Zanycteris			●				
INSECTIVORA	Jepsenella undescribed sp.			●				
INSECTIVORA	?Palaeictops			●				
MULTITUBERCULATA	Mesodma sp.						●	
MULTITUBERCULATA	Neoplagiaulax donglassi						●	
MULTITUBERCULATA	Mimetodon silberlingi			●			●	
MULTITUBERCULATA	Parectypodus sloani n. sp.			●			●	
MULTITUBERCULATA	Ectypodus musculus			●			●	
MULTITUBERCULATA	Ptilodus mediaevus			●			●	●

*On eastern Tornillo Flat. All other localities in this figure are on western Tornillo Flat.

Stage	Locality	Ptilodus mediaevus	Ectypodus musculus	Mimetodon silberlingi	Neoplagiaulax douglassi	Jepsenella	Zanycteris	Plesiadapis gidleyi	Phenacolemur frugivorus	Navajovius kohlhaasae	Psittacotherium	Lampadophorus	Arctocyon ferox	Tricentes truncatus	Promioclaenus acolytus	Haplaletes disceptatrix	Protoselene opisthacus	Phenacodus grangeri	Phenacodus matthewi	Ectocion montanensis	Periptychus superstes	Caenolambda jepseni	Caenolambda pattersoni	Barylambda faberi	Titanoides zeuxis
CLARKFORKIAN	CLARK FORK																								
	BUCKMAN HOLLOW																								
	BEAR CREEK											●													
	PLATEAU VALLEY											●						●						●	●
	OLIVE																								
TIFFANIAN	PRINCETON QUARRY																								
	SILVER COULEE																								
	DELL CREEK																								
	CIRCLE												cf.												
	TWIN CREEK												cf.												
	SCARRITT QUARRY								●				cf.												
	TIFFANY		●					●	●	●								●	●		●				
	BISON BASIN												cf.										●		
	SHOTGUN			cf.	cf.								cf.												
TORREJONIAN	BATTLE MOUNTAIN							●						cf.											
	GIDLEY QUARRY			●		●			●		●				●	●									
	ROCK BENCH			●					●													?●			
	TORREJON	●									●		●	●	●		●								
	LAUDATE																								
	DRAGON										cf.														

Fig. 35.—Range in North America of selected taxa found in the Black Peaks Formation or closely related to taxa found in the Black Peaks Formation. (Information on faunas modified from Russell, 1967.)

	NO. SP. PLESIADAPOID PRIMATES	NO. SP. HYOPSODONTINAE	NO. SP. MIOCLAENINAE	NO. SP. PHENACODONTIDS	NO. SP. PROTOSELENE	NO. SP. PERIPTYCHUS	NO. SP. TITANOIDES
NORTHERN							
CLARK FORK, WYOMING	2	1	-	5	-	-	-
BUCKMAN HOLLOW, WYOMING	3	-	-	4	-	-	-
BEAR CREEK, MONTANA	-	1	-	1	-	-	-
OLIVE, MONTANA	1	1	-	-	-	-	1
SILVER COULEE, WYOMING	1	-	-	2	-	-	3
DELL CREEK, WYOMING	3	-	-	-	-	-	-
CIRCLE, MONTANA	1	1	-	1	-	-	-
TWIN CREEKS, WYOMING	1	2	-	2	-	-	-
SCARRITT QUARRY, MONTANA	2	2	1	6	-	-	2
BISON BASIN, WYOMING	6	4	2	4	1	-	1
SHOTGUN, WYOMING	1	1	1	-	-	1	-
BATTLE MOUNTAIN, WYOMING	2	1	1	3	-	-	-
GIDLEY QUARRY, MONTANA	1	2	2	2	-	-	1
ROCK BENCH, WYOMING	-	-	-	1	-	-	-
SOUTHERN							
PLATEAU VALLEY, COLORADO	-	-	-	4	-	-	2
BLACK PEAKS, TEXAS (43-85M)	2	2	1	3	1	1	1
TIFFANY, COLORADO	1	-	-	4	-	1	-
TORREJON, NEW MEXICO	-	1	9	2	1	2	-
LAUDATE, CALIFORNIA	-	-	1	1	-	-	-
DRAGON, UTAH	-	1	5	-	-	1	-

NOTE: INFORMATION ON FAUNAS OTHER THAN THE BLACK PEAKS FAUNA WAS TAKEN FROM RUSSELL (1967).

Fig. 36.—Geographic distribution in western North America of selected animals and groups during the Torrejonian-Clarkforkian. (Information on faunas other than the Black Peaks fauna was taken from Russell, 1967.)

TABLE 1.—FOSSIL LOCALITIES CITED

Major localities, underlined, are described more fully in table 2 and on pp. 40-41. Several of the locality numbers listed below were first applied in the very early stages of work on the Black Peaks Formation and information on them is not very precise. (Note: feet are given in parentheses.)

<u>41377</u> <u>41274</u>	Approximately 23 m. (75) above base of formation on western Tornillo Flat.
40151	Approximately 23 m. (75) above base of formation in exposure SE of the Chisos Mts. (fig. 1). Only a single mammalian fossil has been recovered from this locality (pp. 20-21). T10 of Wilson (1967, p. 161).
<u>41217</u>	Approximately 43 m. (140) above base of formation on western Tornillo Flat.
<u>40147</u>	Approximately 43 m. (140) above base of formation on eastern Tornillo Flat. T2 of Wilson (1967, p. 159).
40148	General locality including all exposures of formation on western Tornillo Flat. Most fossils with this number were probably collected at or near Ray's Bonebed, since the other major fossil localities were not known at the time this number was being applied. T1 of Wilson (1967, p. 161).
40642 41368	General locality, parking area at end of trail on western Tornillo Flat used to reach Ray's Bonebed area by vehicle. Level in formation falls within range 49-59 m. (160-195) given for Ray's Bonebed and Ray's Annex.
<u>40535</u> <u>40536</u> <u>40537</u>	Ray's Bonebed and Ray's Annex, 49-59 m. (160-195) above base of formation on western Tornillo Flat.
41367	Approximately same level as Ray's Bonebed on opposite side of same hill.
41273	Approximately 56 m. (185) above base of formation, 49 m. (160) below base of black mudstone F on line of section B-B' (fig. 3). Informally referred to as Green Hill.
<u>41365</u> <u>41366</u>	Joe's Bonebed, 79-85 m. (260-280) above base of formation on western Tornillo Flat.
<u>41364</u> 41376	Approximately 105 m. (345) above base of formation on western Tornillo Flat.
<u>41221</u>	Approximately 137 m. (450) above base of formation on western Tornillo Flat.

TABLE 2.—MAJOR FOSSIL LOCALITIES
OF THE BLACK PEAKS FORMATION

All localities except the eastern Tornillo Flat washing site lie on western Tornillo Flat and were included in a previous sedimentological study (Schiebout, 1970). Level in formation is given in meters, feet are in parentheses.

21-23
(70-75)   TMM 41377 (Schiebout-Reeves Quarry), 41274 (washing site and associated float).

Mode of occurrence of fossils: Disarticulated partial pantodont skeleton in place in gray mudstone at Schiebout-Reeves Quarry; loose teeth in calcium carbonate nodule stringers and rare float at the washing site.

Environment of deposition: Floodplain. The pantodont did not undergo transport by water but was weathered and buried in place (p. 40). The teeth and nodules in conglomerates were winnowed from soils and concentrated in small hollows during periods when floodwaters covered the region.

43
(140)   TMM 41217

Mode of occurrence of fossils: Partially articulated pantodont forelimb and partial skull in place in yellow silty mudstone; crocodile bones in float nearby.

Environment of deposition: Pond or swampy area above abandoned channel. Perhaps an oxbow lake. The fossils occurred about 2 m. above the top of a major channel sandstone.

43
(140)   TMM 40147 (eastern Tornillo Flat washing site).

49-50
(160-195)   TMM 40535 (Ray's Annex), 40536 (Ray's Bonebed East), 40537 [Ray's Bonebed West (Taeniodont Locality)]. Ray's Bonebed is called the Needle's Eye locality in some older notes; however, the rock formation from which the name was derived has been destroyed by weathering.

Mode of occurrence of fossils: Most found in float, weathering out of gray or maroon mudstone. Bones are usually encased in a thick concretionary barite crust.

Environment of deposition: Floodplain, near levee. The fossiliferous beds grade horizontally into green and gray siltstones and fine sandstones of the point bar associated with a large channel (fig. 31). Nearness to the river and resulting more frequent saturation of the sediments account for the thick concretions on most porous fossils.

79-85
(260-280)   TMM 41366, 41365 (washing from one conglomerate lens). Both numbers refer to Joe's Bonebed (figs. 8, 9).

Mode of occurrence of fossils: Small teeth in calcium carbonate nodule conglomerate lenses.

Larger mammalian fossils found in float or in place in gray or yellow mudstone or siltstone. No articulated material has been recovered.

Environment of deposition: Floodplain. The tooth-rich conglomerates were produced by reworking in Paleocene floods when teeth and the soil-formed nodules were winnowed out and concentrated in hollows in the floodplain. No in-place concentrations containing fossils larger than loose teeth of *Ectocion* cf. *E. montanensis* have been found; therefore, the force of the floodwaters was not usually sufficient to rework and concentrate them.

105
(345)   TMM 41364 (New Taeniodont site).

Mode of occurrence of fossils: Partial taeniodont skeleton found weathering out of black mudstone layer G (fig. 3). It was impossible to tell if any parts had been preserved articulated. Several other mammalian fossils have been found in float at approximately this level.

Environment of deposition: Swampy, vegetation-rich floodplain. A low energy, reducing environment which may have been water-covered for long periods (p. 42).

137
(450)   TMM 41221 (South Wall).

Mode of occurrence of fossils: All in float, but the topography insures that they have not been transported far since disinterment. No concentrations of fossils have been found.

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TABLE 3.—MEASUREMENTS FOR PTILODUS MEDIAEVUS

Number	Tooth	Length	Width	No. Serrations or Cusps*
41365-687	p^2	3.4	3.4	2:2
-59	p^2	3.4	3.0	2:2
-790	p^2	3.2	3.0	2:2
-786	p^2	3.3	3.1	2:2
-62	p^4	5.2 min.	2.5	0:5:7+ (8)
41274-4	M^1	5.7	2.6	5:9:8
41365-86	M^2	2.7	2.3	—:3:4
-285	M^2	2.8	2.3	—:3:4
40147-42	M_b	8.1	2.9 min.	12
41365-445	M_b	7.2 min.	—	11+ (12 or 13)
40147-47	M_1	4.1 est.	2.1	5:4
-45	M_2	2.1	1.9	3: (2 or 3)
-46	M_2	2.0	1.8	4:3
41365-181	M_2	2.5	1.9	4:3

*The number of cusps in the labial row is listed first. Numbers in parentheses are estimates.

TABLE 4.—MEASUREMENTS FOR ECTYPODUS MUSCULUS

Number	Tooth	Length	Width	No. Serrations or Cusps*
41365-222	p^4	2.9	1.2	1:8
-195	p^4	2.9	1.2	1:8
-695	M_1	2.0	.9	7:5
-528	M_2	—	1.1	4: (3)

*The number of cusps in the labial row is listed first. Numbers in parentheses are estimates.

TABLE 5.—MEASUREMENTS FOR PARECTYPODUS SLOANI N. SP.

Number	Tooth	Length	Width	No. Serrations or Cusps*	H. First Serra.**
40147-67	p^1	—	—	1:2	
41365-286	p^1	1.8	1.1	1:2	
-775	p^1	1.7	1.2	1:2	
40147-36	p^4	2.9	1.4	(2 cusps, 1 cuspule):9	
-37	p^4	2.6	1.3	(1 cusp, 1 cuspule):8	
-41	p^4	2.8 est.	1.2	1:7+ (8)	
41365-113	M_b	3.5	1.3	10	1.9
40147-35	M_b	3.5 est.	1.1	10	1.8
41365-184	M_b	—	1.3	9+ (10)	1.7
-467	M_b	3.6	—	—	1.8

*The number of cusps in the labial row is listed first. Numbers in parentheses are estimates.
**Height of first serration above the anterior enamel base.

TABLE 6.—MEASUREMENTS FOR INSECTIVORA

?Palaeictops (41365-326, M_2)	
a—p length	2.2
trans. tri.	1.8
trans. tal.	1.5

	Jepsenella undescribed species (41365-269, M_2)	Jepsenella praepropera (M_2 of AMNH 35292)*	V**
length	1.3	1.7	7.1
trans. tri.	1.0	1.3	7.0
trans. tal.	0.9	1.2	7.3

*Szalay (1968c, Table 1)
**Minimum coefficient of variation in a population containing both 41365-269 and AMNH 35292 (Simpson et al., 1960, T. 5).

TABLE 7.—MEASUREMENTS FOR *PHENACOLEMUR* *

Species	Number	Tooth	Length	Width	Trans.Tri.	Trans.Tal.
P. frugivorus	41365-682	P^4	1.8	2.1		
	-186	M^2	1.7	2.3		
	-19	M_2	1.7		1.5	1.5
	AMNH 33896	M_2	1.8			
	AMNH 33897	M_2	2.1			
P. fremontensis	AMNH 88309	M_2	1.7	1.3		
		P_4	1.3	0.9		
P. frugivorus	two from	P_4	1.4			
	Scarritt Quarry	P_4	1.6			

Variate	*P. frugivorus* from Scarritt Q. Range	N	*P. fremontensis*	41365-19
$LM_1 : WM_1$	1.2-1.4	3	1.4	
$LM_2 : WM_2$	———		1.3	1.1
$LP_4 : LM_1$	0.8-0.8	3	.76	

*Measurements of *P. fremontensis* are from Gazin (1971, p. 32). Those of *P. frugivorus* not from Big Bend are from Scarritt Quarry, Tiffanian of Montana. Measurements on them, except AMNH 33896 and 33897, are from Simpson (1955, Table 1).

TABLE 8.—MEASUREMENTS FOR
NAVAJOVIUS KOHLHAASAE

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
40147-62	M^2	1.48	2.20		
40537-127	M_1	1.52		1.04	1.16
41365-340	M_1	1.20		.80	.84
-500	M_2	1.32		1.04	1.08
-636	M_2	1.44		.96	1.16
-697	M_2	1.36		1.08	1.12

TABLE 9.—MEASUREMENTS FOR
PLESIADAPIS GIDLEYI

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
41365-327	P^3	2.3	3.3		
-692	P^4	2.7	3.8		
-443	P^4	2.6	3.8		
-73	M^1	3.0	4.1		
-245	M^1	2.8	4.1 min.		
-183	M^2	3.2	4.5		
-150	M^2	3.0	4.4		
-403	M^2	3.0	4.1		
-463	M^3	3.3 min.	4.3		
-31	M^3	3.0	3.9		
-90	P_4	2.7	2.3		
-525	P_4	3.1	2.3		
-291	P_4	2.9	2.4		
-173	M_1	2.9		2.6	2.8 min.
-791	M_1	2.8		2.5	2.8
-399	M_2	3.1		2.9 min.	3.2
-129	M_2	3.3		3.0	3.2
-191	M_1	2.6		2.4	2.6
-541	M_3	4.7		3.0	3.2
41366-77	P_4	2.8 est.	2.3		
-77	M_1	3.1		2.7	2.9
-77	M_2	3.1		2.9	3.0
-77	M_3	4.5		2.8	3.1

	41366-77	*P. jepseni*	*P. anceps*	*P. fodinatus*
L P$_4$	+3.8	+.93	+2.4	——
W P$_4$	+1.4	+4.7	− .06	——
L M$_1$	+1.6	+1.0	+1.6	+5.4
W M$_1$	+1.3	+1.8	+1.3	+1.8
L M$_2$	− .27	+1.5	+2.5	+5.2
W M$_2$	− .25	+1.0	+1.6	+1.6
L M$_3$	−1.1	−1.9	−1.9	+7.2
W M$_3$	+1.8	+ .23	+1.0	+2.5

*Figures are the deviation of an individual specimen (the type for *P. anceps* and *P. jepseni*) from the mean of AMNH *P. gidleyi* divided by the *P. gidleyi* standard deviation as given in Simpson (1935b, p. 6—7). Data on *P. fodinatus* was taken from Simpson (1935b, p. 7), on *P. anceps* from Simpson (1936b, p. 20), and on *P. jepseni* from Gazin (1956a, p. 24—25). Figures over 2 are considered significant and are underlined.

TABLE 11.—MEASUREMENTS FOR
TRICENTES TRUNCATUS

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
41365-810	dP$_4$	5.1 est.		2.2 est.	2.6
-32	P$_3$	3.8	2.2		
40537-88	M$_1$	4.6		3.1	3.2
41365-303	M$_1$	5.2		3.1	3.2
-616	M$_1$	5.3		3.1	3.6
-472	M$_3$	4.9		3.3	3.0
-822	M^1 or M^2	4.3 min.	5.1		

TABLE 12.—MEASUREMENTS FOR *ARCTOCYON*

Species	Number	Tooth	Length	Width
Arctocyon cf. *A. ferox*	41366-81	M^2	14.0	18.3
from Big Bend	-65	M^3	11.0	13.5
"*Claenodon*" [*Arctocyon*]	USNM 20797	M^2	10.7	15.9
cf. "*C.*" *ferox* (Gazin,		M^3	8.2	11.1
1956a, p. 33)				

Species	Tooth	Variate	N	Range	Average
A. primaevus	M^2	length	25	9.8-12.7	11.762±.131
		width	25	13.3-16.4	14.994±.179
	M^3	length	15	7.9-10.6	9.143±.179
		width	,15	9.0-12.1	10.716±.229

TABLE 13.—COMPARISON OF BIG BEND
ARCTOCYON CF. *A. FEROX* WITH THE SMALLER
USNM 20797, *"CLAENODON"*
[ARCTOCYON] CF. *"C." FEROX*

Tooth	Variate	Percent Difference	Approximate minimum V for population containing both (Simpson *et al.,* 1960, Table 5)
M^2	length	30.8	7
	width	15.1	3
M^3	length	34.1	7.5
	width	21.6	5

TABLE 14.—MEASUREMENTS FOR UNDESCRIBED
GENUS AND SPECIES OF ARCTOCYONID

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
41365-168	P^3	5.2	5.3		
-137	P^3	4.8	5.1		
-389	P^4	5.6	7.4		
-764	M^1	6.9	6.9		
-801	M^2	6.5	9.4		
-848	M^2	6.4	9.8 est.		
-38	M^3	6.2	9.0		
-567	P_2	4.9	3.5		
-39	P_2	5.3	3.7		
-633	P_3	5.1	3.9		
-346	P_3	5.3	4.5		
-346	P_4	5.4	4.6		
-342	P_4	5.7 min.	3.9		
-531	M_1	7.0		4.2	4.6
-580	M_1	7.3		4.6	4.9
-805	M_2	8.3		5.7	5.7
-80	M_3	9.0		5.1	5.2 est.
41376-2	M_2	7.2		5.0 min.	5.2
-2	M_3	8.7		5.2	5.0

TABLE 15.—MEASUREMENTS FOR
PROMIOCLAENUS ACOLYTUS

Number	Tooth	Length	Trans. Tri.	Trans. Tal.
41274-10	M_2	3.9	3.6	3.4
	M_3	3.6 min.	2.9	2.4

TABLE 16.—MEASUREMENTS FOR
HAPLALETES DISCEPTATRIX

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
41365-351	M^1	2.7 min.	3.1 min.		
-849	M^3	2.5	3.7		
-457	P_4	2.5	1.4		
-361	M_1	2.7		1.9	1.9
-193	M_2	2.8		2.2	2.2

TABLE 17.—MEASUREMENTS AND STATISTICS FOR *PROTOSELENE*

Variate	AMNH P. opisthacus				USNM 20572 P. novissimus*	TMM 40537-129 P. opisthacus	AMNH P. opisthacus & USNM 20572		AMNH P. opisthacus & TMM 40537-129	
	N	X̄	s	V			t	P	t	P
M_1, length	9	5.2			5.6	4.2 min.				
M_1, trans. tri.	10	4.1			3.6	3.4 min.				
M_1, trans. tal.	10	4.2				3.4				
M_2, length	11	5.3	.20	3.9	5.4	4.6	−.57	.5—.6	1.0	.001—.01
M_2, trans. tri.	11	4.4	.28	6.3	3.8	4.1	2.1	.05—.1	1.1	.2—.3
M_2, trans. tal.	9	4.4				4.1				
M_3, length	12	5.9	.42	7.1	5.5	5.5	.87	.4—.5	.87	.4—.5
M_3, trans. tri.	12	3.8	.27	7.1	3.2	3.4	2.1	.05—.1	1.3	.05—.1
M_3, trans. tal.	12	3.4				3.1				

*Because the average width of trigonid is greater than the average width of talonid in *P. opisthacus,* Gazin's (1956a, p. 41) width measurement is compared to my width-of-trigonid measurement.

TABLE 18.—MEASUREMENTS AND STATISTICS FOR *PHENACODUS GRANGERI*

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
40148-23	dP^3	12.3	10.4		
41366-11	P^3	10.7	10.8		
-60	M^1	10.2	12.7		
-29	P_3	10.1		5.4	5.9
-29	P_4	10.4		7.4	6.7
-29	M_1	11.3		9.5	9.4

Tooth	Variate	N	Range	X̄
P^4	a-p length	2	11.4-11.5	11.5
	trans. width	3	12.3-14.0	13.2
M^2	a-p length	7	10.1-13.2	12.0
	trans. width	8	13.5-16.4	15.2
M^3	a-p length	3	9.3- 9.8	9.5
	trans. width	3	12.2-13.1	12.5
M_1	a-p length	3	11.3-12.1	11.6
	trans. tri.	2	9.5-11.5	10.5
	trans. tal.	4	9.4-10.8	10.1
M_2	a-p length	6	12.1-12.6	12.3
	trans. tri.	4	10.5-12.0	11.2
	trans. tal.	5	9.7-11.7	10.6
M_3	a-p length	8	12.5-14.1	13.2
	trans. tri.	8	9.2-10.7	9.9
	trans. tal.	8	7.4- 9.0	8.2

TABLE 19.—COEFFICIENTS OF VARIATION CALCULATED FOR SEVERAL GROUPINGS OF BLACK PEAKS *PHENACODUS*

Variate	Grouping	V
Length of M^2	all *Phenacodus*	15.3
	P. grangeri	9.9
	P. grangeri without 41366-60 & -69	3.2
	P. matthewi plus 41366-60 & -69	9.6
Width of M^2	all *Phenacodus*	11.4
	P. grangeri	6.6
	P. grangeri without 41366-60 & -69	2.8
	P. matthewi plus 41366-60 & -69	8.3
Length of M_2	*P. grangeri*	1.7
	P. grangeri plus 40148-6	12.9
Length of M_3	*P. grangeri*	5.3
	P. grangeri plus 40148-6	11.9

TABLE 20—MEASUREMENTS FOR
PHENACODUS CF. P. MATTHEWI

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
40147-19	P^4	8.5	9.5		
	M^1	8.4	10.3		
40148-4	M^2	9.3	11.7		
41366-27	M^1	8.5 est.	12.0 est.		
	M^2	8.5 est.	12.1 min.		
40148-6	M_1	7.9		7.0	7.3
	M_2	8.3		7.6	7.4
	M_3	9.1		6.5	5.7
41365-569	M_1 or M_2	8.1		7.4	6.8

TABLE 21.—MEASUREMENTS FOR
ECTOCION CF. E. MONTANENSIS

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
40536-167	M^2	7.8	10.9		
41365-825	M^1	6.9	8.5		
-16	M_1 or M_2	7.6		6.1	5.6
-307	M_3	7.3		6.4	4.8

TABLE 22.—MEASUREMENTS FOR
PERIPTYCHUS SUPERSTES

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
40147-17 (E. Tornillo Flat)	lower molar	9.5 est.		—	8.4
	M^1	8.5	—		
	M^2	8.8	10.8 min.		
40537-59 (W. Tornillo Flat)	P_4	13.3	10.5		
	M_1	13.9		10.6	10.7
	M_2	13.2		10.9	9.6
41367-8 (W. Tornillo Flat)	M^2	12.4 est.		—	—
AMNH 17181*(Tiffany, Colo.)	P_4	12.3	9.1		
	M_1	11.3	9.2		
	M_2	10.5	9.2		
	M_3	14.6	8.9		

*Measurement of type from Simpson (1935b, p. 27).

TABLE 23.—MEASUREMENTS FOR
41377-1, CAENOLAMBDA SP.

Tooth	Length	Width	Trans. Tri.	Trans. Tal.
C Left upper	18.8	11.5		
P	16.9 min.	9.8 min.		
Incisor	4.8			
$\overline{C}$	11.7 min.	11.6 min.		
P_2	9.3 min.	9.5		
P_3	10.5 min.	9.9		
P_4	10.2 min.	9.6 min.		
Left M_1	11.9 min.		9.3	10.0
Right M_1	12.0 min.		9.2	9.6
M_2	13.7 min.		9.7	11.1 min.
Left M_3	16.0 min.		10.5 min.	8.8 min.
Right M_3	16.2 min.		10.2	9.4 min.

TABLE 24.—MEASUREMENTS FOR
BARYLAMBDA JACKWILSONI N. SP.

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
40536-117	M_1 or M_2	27.3 est.		20.0	19.8
40537-83	P_3	16.4 est.	14.2		
	P_4	17.3	17.0		
	M_1	17.1		14.4	12.5
	M_2	19.8		17.3	13.2
	M_3	25.5		16.1	11.5

TABLE 25.—MEASUREMENTS FROM ANTERIOR SIDE OF P_3 TO POSTERIOR SIDE OF M_3 OF FIVE BARYLAMBDID PANTODONTS

Name	Number	R. Side	L. Side
Barylambda faberi	PU 16807 (cast of CNHM 14944)	116.9	118.0
Barylambda jackwilsoni	40537-83	—	95.2
Haplolambda quinni	PU 16445	92.2	—
Leptolambda schmidti	PU 14681	118.2	112.9
Leptolambda schmidti	PU 14680	117.6	—

TABLE 26.—MEASUREMENTS FOR
TITANOIDES ZEUXIS

Number	Tooth	Length	Width	Trans. Tri.	Trans. Tal.
41217-1	$\underline{C}$	12.7	12.5 est.		
	$\overline{P}1$	12.1 min.	11.1 min.		
	$P2$	11.1	14.2		
	$P3$	14.3	16.8		
	$P4$	18.8	18.2		
	$M1$	16.5 min.	19.6		
	$M2$	18.9	23.0		
	$M3$	15.0	24.3		
40536-145	$M1$	13.7 min.	17.9 min.		
40535-79	$M2$	19.2	23.3 min.		
40536-170	$M3$	15.5	21.9		
40537-94	$P4$	11.7	17.4		
	$M1$	13.3	14.7		
	$M2$	15.1	18.4		
	$M3$	12.1	21.4		
40537-73	P_3	11.7	9.0		
41217-5	P_4	13.6 est.	21.3		
41217-1	$\overline{C}$		11.9		
			(max. diam.)		
	P_1	11.2	7.2		
	P_2	12.6 min.	8.3		
	M_2	——		——	11.4
	M_3	22.4		12.8	11.3

TABLE 27.—MEASUREMENTS FOR 41221-8,
HYRACOTHERIUM ANGUSTIDENS

Tooth	Length	Width
$M1$	6.4	7.6
$M2$	7.1	8.4
$M3$	7.1	8.2

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— Willena C. Adams, Editor